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Copulation in the Barred Tree Skink (*Emoia trossula*) from Tonga (Photo: K. Stone).
See article on this on p. 100.

Slender Tree Frog (*Litoria adelaidensis*) (Photo: G. Gaikhorst).
See article on captive reproduction of this species on p. 115.

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CLUTCH DATA AND A RECORD OF DOUBLE CLUTCHING IN MULGA SNAKES (*PSEUDECHIS AUSTRALIS*) FROM CENTRAL AUSTRALIA

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INTRODUCTION

Captive breeding of *Pseudechis australis* has been achieved many times since the discovery that the species is oviparous (Fitzgerald & Pollitt, 1981). Fyfe (1991) provided captive breeding observations of the central Australian form of *P. australis*. Double clutching (depositing two clutches during a single breeding season) has been recorded in captivity for several other oviparous elapids, including the Inland Taipan (*Oxyuranus microlepidotus*), Coastal Taipan (*Oxyuranus scutellatus*), Western Brown Snake (*Pseudonaja nuchalis*) and Eastern Brown Snake (*Pseudonaja textilis*) (Greer, 1997). However, this reproductive trait has never been recorded for any member of the genus *Pseudechis*. We here record *P. australis* producing two clutches in one season.

OBSERVATIONS

During March/April 2007, the Alice Springs Desert Park (ASDP) acquired a pair of central Australian *P. australis*, both of which originated in the wild. The female was an old animal that had been in captivity for at least 12 years. The male had only been in captivity for four years and appeared significantly younger. Both animals were of similar size (female 1.6 m, male 1.7 m), making them suitable for display together. After a quarantine period during which they were housed separately, the snakes were introduced into the display enclosure in August 2007, with a feeding regime of two adult mice per snake per fortnight (approximately).

On 19 October 2007 courtship behaviour was noticed but no copulation was observed. The female gained considerable mass over the next few weeks and on 13 November she had her "pre-lay" shed. On 29 November, the female appeared restless and was trying to get underneath grasses and logs by prodding her nose into the soil. To facilitate egg laying, she was moved into a holding enclosure with two separate hide structures that contained moist sphagnum moss.

On 30 November, 17 days after sloughing, the female commenced depositing eggs at 1300 hrs, a process which continued until approximately midnight. On the morning of 1 December the 16 eggs were carefully removed, weighed and measured (Table 1). The female was laying on top of the eggs but did not exhibit protective behaviour when initially disturbed or during subsequent removal from the enclosure. All the eggs appeared fertile and were incubated in a 1:1 mix (by weight) of Perlite and water at a temperature of 28°C for the first week and 31°C for the remainder of the incubation period.

After egg deposition the female was returned to the display enclosure, commenced feeding a few days after her return, and was main-

Table 1. Egg Data (mean in parentheses). RCM = relative clutch mass (total egg mass/female post-oviposition mass)

	Clutch Size	Length (mm)	Width (mm)	Mass (g)	RCM
Clutch 1	16	46.64-61.04 (54.16)	25.34-28.56 (27.25)	22.16-25.53 (24.25)	0.49
Clutch 2	10	49.42-56.75 (53.39)	23.37-26.02 (24.98)	18.51-24.24 (20.78)	0.32

tained on her normal feeding regime. No mating behaviour was observed after her reintroduction to the male.

Eleven days into incubation, one egg was observed to have fungus growing on the outside and was removed from the clutch and opened. The egg was fertile, with blood vessels and a partially formed embryo. Two weeks later another egg was removed due to the presence of fungus; this egg proved to be infertile. On 31 January 2008, several eggs began to collapse and on 10 February, 72 days into incubation, a number of eggs were observed to have been slit. Over the following three days, all 14 remaining eggs hatched and the neonates were weighed and measured (Table 2).

During the late afternoon on 15 February 2008, 77 days after the first clutch of eggs was laid and 20 days after sloughing, the female was observed depositing a second clutch in the display enclosure. This was a surprise as there was no previous record of the species producing two clutches in a single breeding season. When checked the following morning, egg deposition had been completed. The nest site was a shallow depression in the substrate, with the female laying on top of the eggs. All ten eggs were removed for weighing and measuring as for the first clutch (Table 1). This second clutch of eggs was not incubated. While it was not possible to determine whether the eggs were fertile, they were similar in size and form to the eggs of the first clutch, and we have no reason to consider that they would not have been fertile.

DISCUSSION

Very few data have been published on the eggs of *P. australis*. Our measurements are much larger than those reported by Bush (1995) for a clutch of equal number (16) produced by a considerably smaller (1.15 m) female from north-western Australia (mean 40 x 23 mm, 13 g). Maryan (2000), however, has documented a smaller clutch (n = 9) of larger eggs (mean 59 x 26 mm, 32.1 g) from a successful breeding of *P. australis* from south-western Western Australia. The relative clutch mass (RCM; clutch mass/female post-oviposition mass) for the first clutch here was noticeably greater than that reported by Maryan (0.49 vs 0.35), while the second clutch was comparable (0.32). Two clutches combined represent a markedly higher reproductive commitment over the duration of a single breeding season.

The size of captive-bred *P. australis* neonates has been documented on several occasions. Fyfe (1991) hatched eggs from a central Australian *P. australis*. Although only snout-vent length was measured for those hatchlings (mean = 312 mm), extrapolation of the measurements (350+ mm) indicates that total lengths would have been comparable to the present study. Central Australian *P. australis* hatchlings appear to be longer than con-

Table 2. Hatchling data from Clutch 1. Lengths accurate to +/- 5 mm.

Hatchling #	Total length (mm)	Mass (g)
1	370	16
2	370	17
3	360	16
4	375	15
5	350	15
6	370	14
7	385	16
8	370	16
9	360	15
10	340	13
11	340	11
12	375	16
13	375	17
14	360	14
Mean	**364**	**15**

specifics from northern Western Australia (mean 240 mm SVL; Bush, 1995), south-western Western Australia (mean 273 mm total length; Maryan, 2000), eastern Queensland (mean 220 mm SVL; Fitzgerald & Pollitt, 1981), and Eyre Peninsula in South Australia (mean 327 mm total length, Mirtschin, 1988).

Interestingly, this does not equate to heavier neonates in the central Australian form. The average weights of hatchlings recorded here and by Fyfe (1991; mean = 13 g) are intermediate between those documented by Bush (1995: 9.4 g) and Fitzgerald and Pollitt (1981: 8.0 g) and those hatched by Mirtschin (1988: 15.7 g). Maryan (2000) reported markedly higher hatchling weights for south-western WA *P. australis* (17 g), despite those individuals being on average 90 mm shorter in length.

While double-clutching has rarely been documented in non-captive Australian elapids, Shine (1991) reported that wild Speckled Brown Snakes (*Pseudonaja guttata*) in western Queensland (Greer, 1997: 154, corrected the locality from western New South Wales, from where that species has never been recorded) produced at least two clutches over summer after an abnormally good season provided plentiful food. The variability of the climate and rainfall patterns in arid Australia means that such exceptional seasons do occur on an infrequent basis, interspersed between often long periods of below-average rainfall. The ability of central Australian *P. australis* to produce a second clutch would allow the species to exploit the short-term abundance of prey experienced when good environmental conditions prevail.

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We would like to thank the Alice Springs Desert Park for providing the time and resources to work on the captive breeding of Mulga Snakes. We would also like to thank the following persons who have contributed in various ways: Rex Neindorf and the Alice Springs Reptile Centre for providing ASDP with the breeding pair of snakes, Anne and Margaret from the Arid Zone Research Institute library for sourcing countless papers and reference material, Greg Fyfe for his ongoing support to research of arid zone species and for providing detailed information about captive breeding of Mulga Snakes, and Peter Mirtschin for providing us with captive breeding data on Eyre Peninsula Mulga Snakes.

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AN INSTANCE OF SENESCENCE IN A FIELD POPULATION OF THE EASTERN BEARDED DRAGON, *POGONA BARBATA* (LACERTILIA, AGAMIDAE)

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Survival to old age or senescence is rarely observed in animal populations outside the captive environment. In an attempt to increase our knowledge of this phenomenon, an incidental observation of the transition from healthy maturity to senescence in an adult male *Pogona barbata* is provided.

METHODS

A field population of the Eastern Bearded Dragon, *Pogona barbata*, was monitored over a period of 2.5 years (September 1994 - March 1997) for a reproductive biology project (Amey, 1999; Amey & Whittier, 2000a,b; Cree *et al.*, 2000). The population was resident at the Laidley Golf Course, approximately 60 km west of Brisbane (27°37'S 152°23'E). The golf course's roughs were open woodland of *Eucalyptus tereticornis* and other trees with a low grassy understorey. Most lizards were observed in the rough of 2.8 ha area bordered by the 1st, 2nd and 3rd fairways. Densities could be quite high, with up to 31 sightings each day (average 16) during the breeding period (approximately September-December). Generally, animals were caught by hand once a month, weighed and measured with a rigid ruler (snout-vent length) and a blood sample was taken. They were then released, usually within five minutes. During the breeding period, behavioural observations were made which did not involve capture or other disturbance. For these observations, identification numbers were applied with paint-pen so animals could be identified without the need of re-capture. For further details, see Amey (1999).

OBSERVATIONS

The focus animal (field number 9494) was first observed as a large adult male on 20 September 1994 (Figure 1). At this time, it was a territory holder, actively patrolling its area, displaying with arm stamps and head bobs and courting females (Amey, 1999; Brattstrom, 1971). It was observed mating twice (22 October 1994; 9 November 1994). Observations were not continuous so unobserved matings are likely. By the end of this breeding season, it was observed with damage to its lower jaw consisting of skin torn away from the tip (21 December 1994). This type of injury was very common in male *P. barbata*, presumably resulting from combat with other males. The scarring was still visible when it was observed at the next breeding season (12 September 1995). By the end of this season (14 December 1995), the individual had lost a finger and its right forelimb was swollen and evidently infected. It was next encountered at the height of the next breeding season (16 September 1996) by which time there was a marked deterioration. Both forelimbs were swollen, limp and deformed and appeared to be painful to touch. That both limbs were similarly affected suggests a general physiological condition, such as arthritis, rather than a traumatic injury. The animal had difficulty climbing trees (this species' usual method of escaping predators) and was instead hiding in low undergrowth and struggled only weakly on capture. The jaw muscles, which usually bulge dorsally behind the eyes, were sunken. It had not moulted as the paint-pen identification markings from the year before had not been lost, in contrast to the other lizards marked. Its weight was not regained from the previous breeding season's loss. It was evidently no

longer a territory holder as the next day (17 September 1996) it was observed lying still in long grass at the base of a tree while another large male asserted its dominance over the territory with characteristic head bobbing and arm stamping.

This individual was seen once more in the post-breeding summer period (20 February 1997). Its weight had marginally increased, but its jaw muscles were still sunken and its forelimbs were still swollen and crippled. However, it seemed to be in better overall health than the previous observations, in that its limbs were not painful to touch and it struggled vigorously during capture and measurement. The last observations at the site were made in March 1997 and the focus individual was not seen again. While this individual's weight fluctuated considerably over the observation period (7 observations, $r^2 = -0.188$, slope n.s.), its snout-vent length showed a slight but statistically significant increase (7 observations, slope of 0.0146 mm/day, $r^2 = 0.757$; $t = 4.435$, $p = 0.007$).

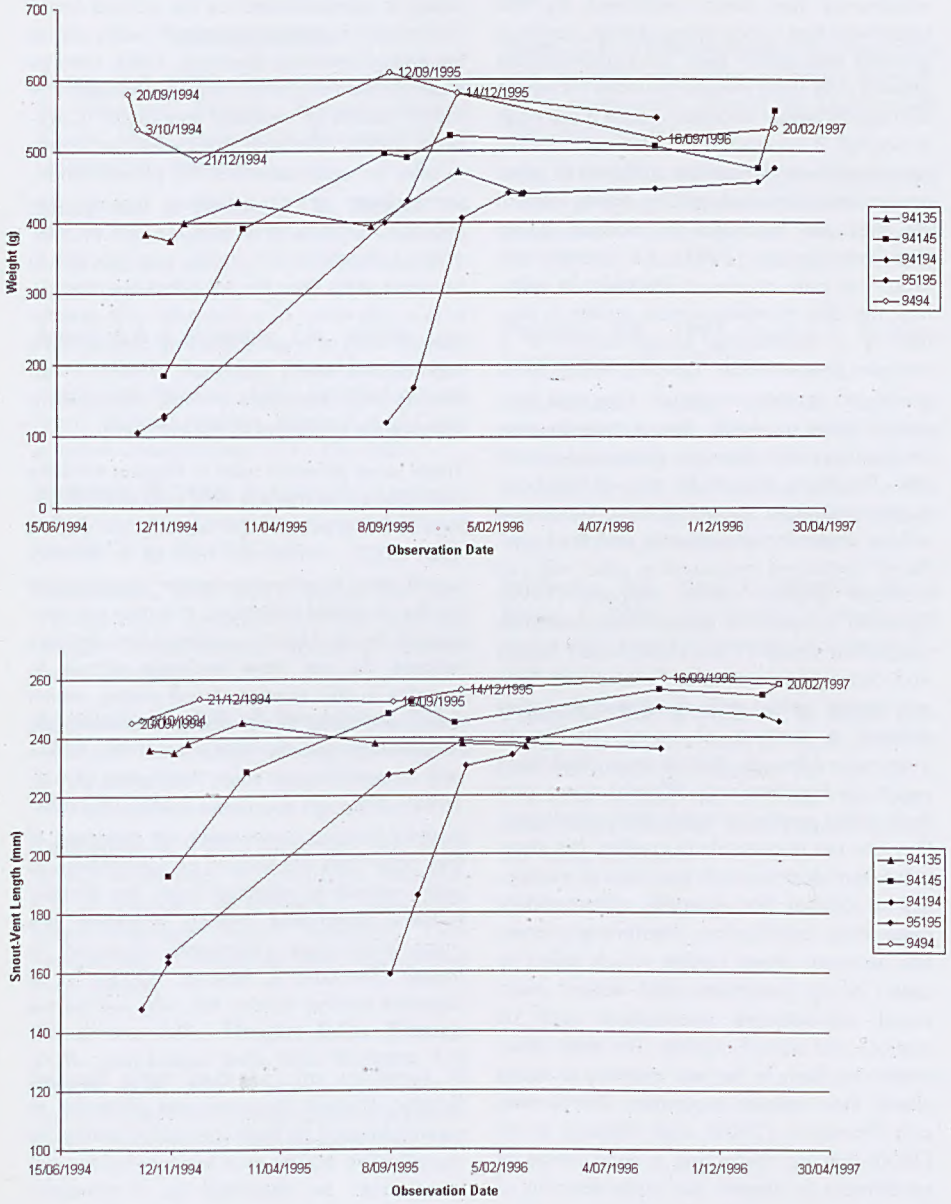
DISCUSSION

The present example is only a single individual living in an artificially modified environment (a golf course), so it is impossible to gauge the prevalence of senescence in this species. However, it does provide evidence that males of this species can survive beyond their period of maximum reproductive activity under fairly natural conditions. The individual was still subject to predation risk, the elements, conspecific competitors and had to find shelter and sufficient food.

In the first breeding season monitored (1994), the subject animal lost weight (Figure 1). It had regained that weight by the start of the next breeding season. This could be interpreted as normal breeding season weight loss due to the stresses of maintaining a territory, fending off rivals and courting females, with the weight then being regained in the summer. Weight and snout-vent length changes of other mature males are provided in the figure for comparison. As the individual's physical condition only deteriorated markedly by the end of the second breeding season (1995) and behavioural changes were only observed during the third breeding season (hiding in long grass while another male performed dominance displays in 1996), it seems he was 'deposed' as a territory holder sometime between these observations. Whether his injuries resulted from combat with another male, a predation attempt or some other incident or disease is not known. In contrast to other mature males, consistent weight loss was observed during and after the 1995 breeding season. Loss of territory and injury may have limited his ability to forage and recover. *Pogona barbata* individuals often have heavy parasite loads (personal observations) and this may exacerbate weight loss in times of stress. By the third breeding season (1996), the animal's condition was so poor it was not expected to be seen again. The last observation before the conclusion of the study (two months after the 1996 breeding season) was therefore a surprise, more especially as the animal's condition had improved. Weight loss had halted, although it had not regained weight, and it was strong enough to struggle vigorously against capture. Its injuries, particularly the crippling of its front limbs, appeared permanent and its jaw muscles were still sunken. It seems unlikely it would have been able to hold a territory again but it had been able to forage and regain health. It remained near or even within its former territory, probably by remaining inconspicuous and avoiding its 'successor'. As it had lost access to reproductive opportunities (through being a successful territory holder), was permanently injured and had lost weight, while regaining health, it would seem to fit a characterisation as senescent, or showing signs of age, even though its reproductive capacity (that is, its ability to produce viable sperm), is unknown.

Published evidence for the existence of senescence in reptiles is scant and contradictory. The long-lived turtles *Chrysemys picta* and *Emydoidea blandingii* show no evidence of it (Congdon *et al.*, 2003), nor does the garter

Figure 1. Weight (a) and snout-vent length (b) measurements of male *Pogona barbata* individuals, including 9494, the subject of this paper (hollow circles).



snake, Thamnophis elegans (Sparkman *et al.*, 2007; for a comparative discussion, see Finch, 1998). In fact, female reptiles often show higher reproductive output or success as they age. A lack of aging in reptiles and other ectotherms has been explained by the hypothesis that, since many reptiles continue growing throughout their life (indeterminate growth) and since female fecundity increases with size (a bigger body can house more eggs or young), it is possible that the reproductive benefits of living longer are sufficient to select against the deleterious alleles acting later in life that are theorised to produce aging (Sparkman *et al.*, 2007). Of course, this argument only applies to females. In addition, the idea of indeterminate growth in reptiles is a misleading simplification of a complex phenomenon. Typically, lizards grow quickly to a near maximum size and then growth slows markedly. Sexual maturity may be reached well before any plateau of growth rate. Therefore, it could be argued that once a near-maximum size is attained, clutch size will no longer increase greatly and the benefits of continuing reproductive effort will not increase greatly either. Patnaik (1994) reviewed a range of experimental evidence suggesting aging in some short-lived lizards and snakes (for example, *Calotes versicolor* and *Natrix natrix*) and concluded that they showed a pattern of aging similar to mammals. Although Patnaik reconciled these results by hypothesising different aging patterns within reptiles (a highly likely possibility), they are not necessarily in conflict. His characters that declined with age were physiological or cellular (for example, mitochondrial respiration, calcification, membrane properties) whereas those studies which failed to detect aging (examples cited above) measured reproductive parameters such as number and size of clutches. The latter characters are likely to be less sensitive to aging effects than cellular properties. Bronikowski and Promislow (2005) and Williams *et al.* (2006) call for measuring a wide range of parameters to deepen our understanding of this complex process.

It is noteworthy also that studies of reproductive senescence in reptiles confine themselves to females only. This is understandable since female reproductive output is much easier to measure. An extreme case of male senescence is demonstrated by the scincid lizard *Trachylepis buettneri*, where all males die at the end of breeding (Barbault, 1986, cited as *Mabuya buettneri*) in a manner reminiscent of many species of dasyurid marsupial (Cockburn, 1997). Although data were too scanty to offer an explanation for this phenomenon, some form of kin-selection benefit (for example, increasing female survival by lessening competition for food), was thought to be more likely than the idea that the mortality is a side effect of a character with greater benefit, such as a gene allowing greater early reproductive effort (Barbault, 1986). I can find no other examples of male reproductive senescence in reptiles in the literature.

There is no parental care in *Pogona barbata* after laying, so there is little selective advantage to living beyond the reproductive period (Lee, 2003). While the loss of a territory would seem to end reproductive opportunities for the observed individual, this may not necessarily be so. There is evidence that territory holders do not have exclusive access to females in this species. Small males, which have no chance of defending a territory, are nonetheless sexually mature and live within and around large male territories (Amey, 1999). Although successful matings by non-territory holding males were not observed, if they occur they are likely to be surreptitious to avoid attracting attention from the territory holders. Alternative mating strategies are more and more commonly observed in lizards (Zamudio & Sinervo, 2003). For a deposed territory holder, this may well be the option it returns to.

In summary, an individual male Bearded Dragon (*Pogona barbata*) was observed to survive beyond its likely period of maximum reproductive activity as a territory-holder into what could be described as a senescent period of its life. Its survival may have allowed

it to gain extra matings by remaining inconspicuous near its former territory. While this observation suggests senescence can occur in wild populations of this species, its prevalence is unknown.

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FIRST RECORD OF THE BRAHMINY BLIND SNAKE, *RAMPHOTYPHLOPS BRAMINUS* (SERPENTES: TYPHLOPIDAE), FROM SAMOA, SOUTH PACIFIC

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[3]The Australian Museum, College St, Sydney, NSW 2000.

The Brahminy Blind Snake, *Ramphotyphlops braminus* (Daudin, 1803), has one of the most widespread distributions in the world for any terrestrial reptile, having been recorded from Asia, Africa, north and central America and Australia, as well as numerous oceanic islands (Ineich & Blanc, 1988; Ota *et al.*, 1991). Over most of its distribution it has been introduced through recent human activity, and this has been facilitated by several aspects of its biology: small size and fossorial activity, allowing it or its eggs to be readily transported in soil without detection; parthenogenetic reproduction (Wynn *et al.*, 1987), allowing new populations to readily establish from small founder groups; the ability of snakes to survive for long periods without feeding, allowing accidental transport of adults over long distances and durations, and an incubation period of up to 58 days (Ota *et al.*, 1991), similarly allowing eggs to successfully survive transport over long distances.

Within the South Pacific, *R. braminus* has a patchy distribution reflective of varying human transport (Crombie & Pregill, 1999). It has been recorded from Nauru (Buden, 2008), Guadalcanal in the Solomon Islands (Loveridge, 1957; McCoy, 2006), four islands in Vanuatu: Efate (Medway & Marshall, 1975), Espiritu Santo (Shea & Wallach, 2000), Ambrym (de Pous & Dingemans, 2008) and Toga (Ineich, 2009), as well as from a number of localities in the Grand Terre of New Caledonia (Bauer, 1987; Ineich & Bauer, 1992; Bauer & Sadlier, 2000) and Maré in the Loyalty Islands (Shea & Wallach, 2000). Further to the east, it has been reported around Suva in Fiji (Morrison, 2003), and from Tutuila in American Samoa (Craig, 2002; Goldin, 2002). Although a single individual has been intercepted in transported materials arriving in New Zealand (Gill *et al.*, 2001), it has not yet established there.

To the north of the Equator, it is known from the Bonin Islands (Shigei, 1971), the Northern Mariana Islands and Guam (Van Denburgh, 1917; Cagle, 1946; Wiles *et al.*, 1989, 1990), Palau (McDowell, 1974; Crombie & Pregill, 1999; Wallach, 2008), the Federated States of Micronesia (McDowell, 1974; Buden, 2000), the Marshall Islands (Knight, 1984; Wallach, 2008) and Hawaii (Slevin, 1930; Lieberman & Lieberman, 1970; McKeown, 1996).

However, it has not been reported to date to have spread further into the South Pacific, as it has not been found among herpetological collections from Rotuma (Zug *et al.*, 1989), Wallis and Futuna (Gill, 1995), Tuvalu (Waite, 1897), Tokelau (Whitaker, 1970; Clapp, 1975), Kiribati (Moul, 1954; Clapp & Sibley, 1971a,b; Kepler *et al.*, 1994), Tonga (Gill, 1987, 1988, 1990; Gill & Rinke, 1990; Steadman *et al.*, 1999), Niue (Wodzicki, 1969), the Cook Islands (McCann, 1974; Clapp, 1977; Crombie & Steadman, 1986; Gill, 1998), French Polynesia (Ineich & Blanc, 1988) or the Pitcairn Island Group (Gill, 1993a).

The most recent survey of the herpetofauna of Samoa was by Gill (1993b), who did not record any typhlopids from the country. Typhlopids were similarly not found in an earlier collection (Higgins, 1943). However, on 19 May 2009, two *Ramphotyphlops braminus* (Australian Museum R171936-37)

were collected from wasteland (representing a recently demolished building) along Beach Road at Mata'utu-Tai (13°49'45.0"S 171°45'33.2"W), Apia, on the island of 'Upolu, by Makerita Toomalatai. The locality is close to the Apia Harbour Wharf, the main transportation port for the island.

The two specimens were identified as *Ramphotyphlops braminus* by their small size (SVL 69, 99 mm), dark coloration dorsally and ventrally with a pale patch on the chin and vent, 20 midbody scales, nasal cleft contacting the preocular scale, and prominent glands under the head shields (McDowell, 1974; Ota *et al.*, 1991).

The finding of one individual of just greater than hatchling size, and another towards the upper end of immaturity or lower end of maturity (Cagle, 1946; Ota *et al.*, 1991) on a single occasion suggests that a reproducing population is established at this site. The close proximity of the site to a shipping wharf suggests the population arose from transported materials.

Samoa has no native fossorial reptiles (Gill, 1993b), so the introduction of *R. braminus* is not likely to provide any direct competition for native vertebrates. Its likely effect on the small invertebrate fauna is unknown; we are unaware of any studies on the diet of the species.

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A SIGNIFICANT RANGE EXTENSION FOR THE EASTERN BROWN SNAKE (*PSEUDONAJA TEXTILIS*) IN THE NORTHERN TERRITORY

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On 26 April 2009 a large (snout-vent length approximately 140 cm) road-kill elapid was encountered by two of the authors (GC and PM) on the Stuart Highway (15.8981°S 133.4202°E), approximately 45 kilometres south of Larrimah, Northern Territory (Figure 1). The animal was identified as belonging to the genus *Pseudonaja* by the presence of an undivided anal scale, 17 scale rows at midbody, a single temporal scale between the fifth upper labial and parietal scale, and orange blotches on the ventral surface (Cogger, 2000). A pink mouth lining confirmed the identity as *P. textilis* (Gillam, 1979; Wilson & Swan, 2008) (Figure 2). Photographs of these key features were sent to Paul Horner (Northern Territory Museum) who verified our conclusion. The snake was not lodged as a specimen due to considerable damage from road traffic.

At the collection locality, the Stuart Highway runs through a slightly undulating plain with grey clay soil and low rises. Vegetation consisted of low open woodland of *Eucalyptus pruinosa* and *Bauhinia cunninghamii* with scattered *E. leucophloia* on the rises. A sparse shrub layer was present over dense perennial grasses and herbs. This vegetation is characteristic of a transitional zone between woodland and wetland and this was confirmed by examination of the area on Google™ Earth, with a seasonally inundated plain and associated watercourse (Birdum Creek) clearly visible one kilometre west of the highway.

Birdum Creek, which connects with several minor drainages to the south, links our record with the northernmost tip of the 'black soil' plains of the Barkly Tableland (approximately 100 km south), where a population of *P. textilis* has previously been reported (Gillam, 1979). Perhaps clay drainages and swamps, which can be highly productive and are likely to offer improved food resources over the surrounding woodlands (Madsen & Shine,

Figure 1. Map of the Northern Territory showing all previous records of *P. textilis* (circles) and the new record reported here (triangle). The grey lines represent mean annual rainfall isohyets labelled in millimetres. Previous records sourced from the NT Fauna Atlas (June 2009).

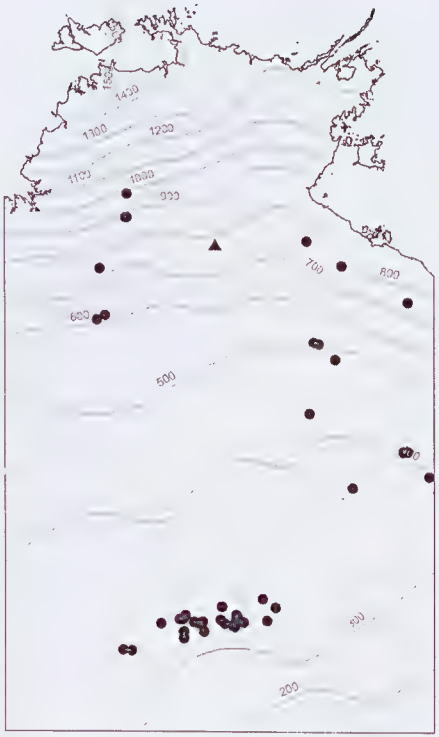

Figure 2. Head and mouth of the road-kill *P. textilis* encountered on the Stuart Highway in the Northern Territory. The pink mouth-lining identifies it from all other species of *Pseudonaja* which occur in the Northern Territory.

1996), allow *P. textilis* to penetrate into these latitudes of the Northern Territory where rainfall is highly seasonal. Only further investigation and more specimens will confirm whether this is the case or whether the species has a broader distribution across the savannah woodlands of the southern Top End.

Importantly, our record links previous records in the Gulf and Barkly (nearest record 200 km to the east) with records from the Victoria River district and Ord River plain (nearest record 200 km to the west) (Figure 1). Notwithstanding the possible association with clay drainages, this suggests a more continuous distribution across the 600 to 1000 mm rainfall zone of the Northern Territory than has been previously reported (Gillam, 1979).

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SURVEYS OF THE REPTILES AT BUDDEROO NATIONAL PARK AND ENVIRONS ON THE SOUTH COAST OF NEW SOUTH WALES

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ABSTRACT

Populations of reptiles were monitored in Budderoo National Park near Robertson on the south coast of New South Wales. Fourteen 0.5 hectare plots (50 x 100 m) were surveyed once in 2002 and again after a wildfire in 2003 for 60 minutes each. The plots covered a range of vegetation communities and were located at similar high altitudes. The number of Southern Water Skink *Eulamprus heatwolei* and Grass Skink *Lampropholis delicata* detected after the fire was fewer but the number of Black Rock Skink *Egernia saxatilis* was greater. Combined species richness at plots was seven pre fire and nine post fire. A total of eighteen species of reptile has been recorded for the park. We detected the White-lipped Snake *Drysdalia coronoides* in the park and the Copperhead Snake *Austrelaps ramsayi* in areas adjacent to the park. These species are typical of highland landscapes, such as Budderoo National Park.

INTRODUCTION

Systematic surveys of reptiles in New South Wales only received attention in the early 1980s when a few assessments considered the impacts of logging (Lunney *et al.*, 1981; Webb, 1991). With the gazettal of the Endangered Fauna (Interim Protection) Act 1991, a series of investigations were undertaken in areas where timber extraction occurred (Clancey, 1992; Austeco Environmental Consultants, 1994; Smith, *et al.*, 1994; Ecotone Ecological Consultants, 1995; Mount King Ecological Surveys, 1995; Smith *et al.*, 1995; Goldingay *et al.*, 1996; Wellington and Wells, 1995).

During the late 1990s systematic surveys of fauna and flora were conducted for the Comprehensive Regional Assessment (CRA) in every state and territory in an attempt to gather information on distribution of species in respect to the adequacy of the reservation system. Systematic surveys for reptiles were conducted as part of the CRA process and a selection of results have been published from that data for the southeast coast, southern tablelands and highland regions of NSW (Daly *et al.*, 2001; Daly 2004, 2006, 2007). These broad scale systematic surveys provide future research data that may be used for future comparative studies. They also provide information on the diversity, species richness and habitat corridors in some regions.

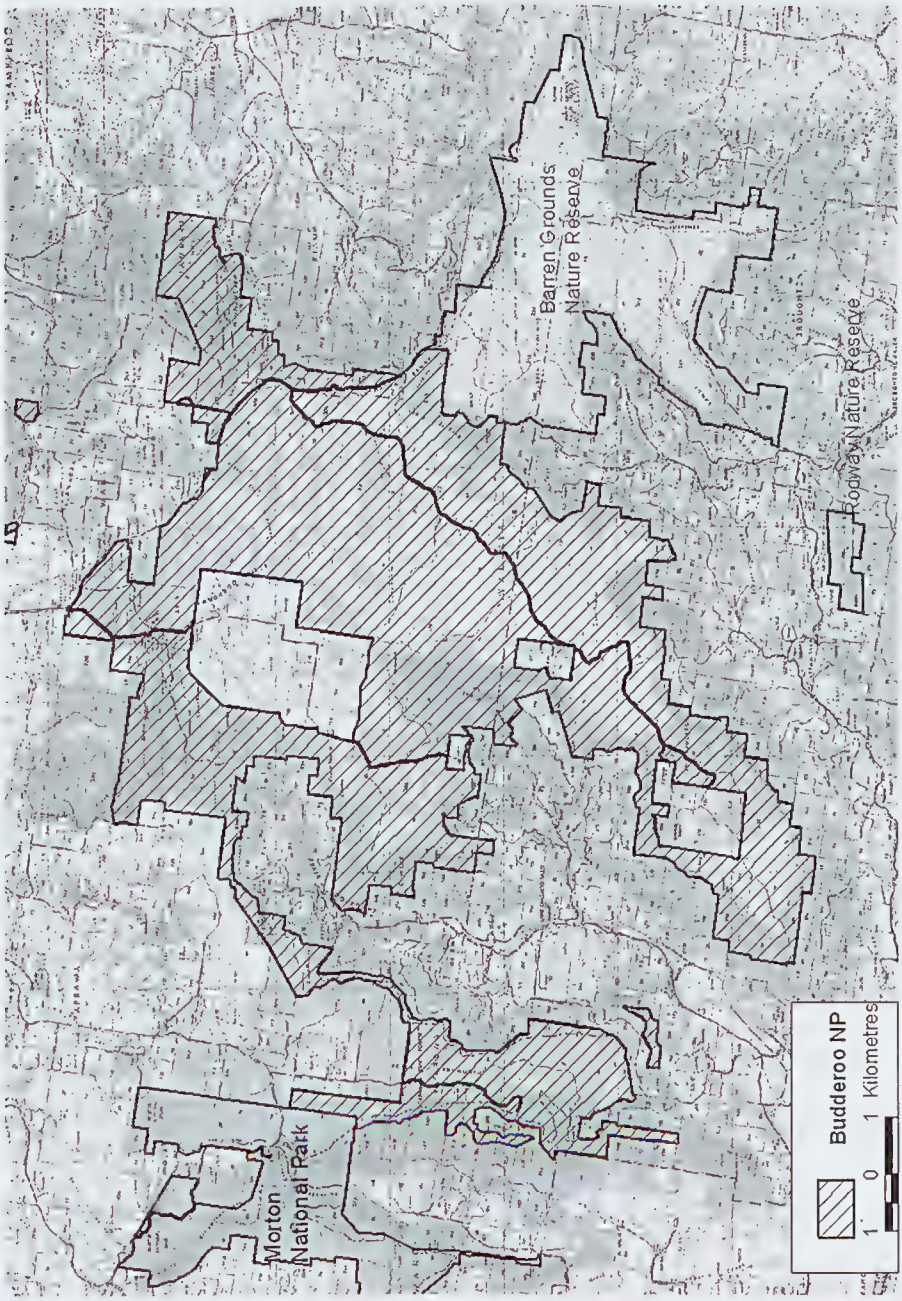
This paper presents information on the species of reptile observed in Budderoo National Park using methods developed as part of CRA process. The data augments other studies conducted by the senior author in an attempt to provide baseline information on the region's herpetofauna. Comment is provided on habitat corridors in the region. In December 2002 fire burnt approximately 2650 hectares of the park (I. Jackett, pers. comm.), including nine of the 13 sites. The sites surveyed earlier in that year were resurveyed in early 2003 to quantify changes in the density and species diversity in respect to fire.

METHODS

Study area

Budderoo NP (35°10'S 150°30'E) is located on the southern highlands between Robertson and Jamberoo on the south coast of New South Wales. The climate is mild (average range of 16 - 24°C in summer and 8 - 15°C

Figure 1. Budderoo NP adjoins Barren Grounds Nature Reserve (2029 ha) to the east, and Morton NP (196,065 ha) to the west



in winter). The average temperatures are influenced by the region's elevation being 160 - 650 m AHD (Australian Height Datum). The Kangaroo Valley 1: 25 000 topographic map indicates that the average annual rainfall for the region is 1230 mm occurring fairly evenly throughout the year (less rain in spring). Budderoo NP was gazetted in 1986 and is currently 7120 hectares. Budderoo NP adjoins Barren Grounds Nature Reserve (2029 ha) to the east, and Morton NP (196,065 ha) to the west (Figure 1).

Geology and soil

The Kiama soils landscape sheet (Hazelton, 1993) states that the Barren Grounds landscape has gently undulating rises with poorly drained depressions. The underlying rock is primarily Hawkesbury Sandstone and soils derived from this landscape have low fertility and are subject to waterlogging.

Budderoo NP (and Barren Grounds NP) has rock outcrops and a thin layer of sandy soil derived from the Hawkesbury Sandstone but there are small sections which have deeper soil derived from the Gerringong Volcanic intrusions. As a consequence of the more fertile soils, much of the freehold land within and adjacent to the reserve has been cleared for agriculture.

Hazelton (1993) shows that to the north of Budderoo/Barren Grounds the geological landscape and resulting soils are primarily

Table 1. Broad vegetation communities where reptile survey plots were located.

Community name	Principal species
Coastal Sandstone Plateau Heath	Trees: *Corymbia gummifera*. Shrubs: *Isopogon anemonifolius, Banksia ericifolia, Lambertia formosa, Epacris microphylla, Leptospermum trinervium, Hakea teretifolia, Pimelea linifolia; Hakea laevipes, Banksia oblongifolia, Pultenaea elliptica, Petrophile pulchella, Xanthorrhoea resinifera*. Groundcover: *Dampiera stricta, Lepyrodia scariosa, Actinotus minor, Cyathochaeta diandra, Lindsaea linearis, Lomandra obliqua*.
Blue Mtns - Morton Hanging Swamps	Shrubs: *Leptospermum juniperinum, Baeckea linifolia, Sprengelia incarnata, Epacris obtusifolia, Hakea teretiofolia, Banksia ericifolia*. Groundcover: *Empodisma minus, Leptocarpus tenax, Gymnoschoenus sphaerocephalus, Lepidosperma limicola, Drosera binata, Xyris operculata*.
Budderoo-Morton Plateau Forest	Trees: *Corymbia gummifera, Eucalyptus sieberi, E. piperita*. Shrubs: *Bossiaea kiamensis, Aotus ericoides, Banksia paludosa, Leptospermum trinervium, Amperea xiphoclada, Acacia obtusifolia, Banksia serrata, Epacris longifolia*. Groundcover: *Lomandra longifolia, Gahnia sieberiana, Gleichenia dicarpa, Empodisma minus*.
Escarpment Foothills Wet Forest	Trees: *Eucalyptus muelleriana, E. smithii*. Shrubs: *Synoum glandulosum, Notelaea venosa, Elaeocarpus reticulatus*. Climbers: *Smilax australis, Tylophora barbata, Eustrephus latifolius, Geitonoplesium cymosum, Hibbertia dentata, Pandorea pandorana*. Groundcover: *Pteridium esculentum, Microlaena stipoides, Dianella caerulea, Oplismenus imbecillis*.

derived from Robertson basalts and shales (Wildes Meadow). Hawkesbury sandstone is restricted to a comparatively thin band along the steep escarpment. This situation also occurs to the west of Budderoo NP around Fitzroy Falls. Hence Budderoo and Barren Grounds NPs have expanses of slightly undulating Hawkesbury sandstone that have weak links to similar geologies to the north in the Metropolitan Special Area of the Sydney Catchment and to the south-west in Morton NP.

Vegetation communities

The native vegetation in the reserve is primarily heath and woodland. However there were small areas of open forest and tall open forest in areas where the soil is more fertile and had greater depth. The main canopy species in the woodland and open forest were Silvertop Ash *Eucalyptus sieberi* and Red Bloodwood *Corymbia gummifera*. Tozer *et al.* (2006) described the vegetation in the region (Table 1). There were differences in the vegetation communities described by Tozer *et al.* (2006) to those verified by field inspections made by Black (2000) and Proust (2001) (Table 2). In particular, at site 6 the main canopy species in the tall open forest consisted of Monkey Gum *E. cypellocarpa*, River Peppermint *E. elata* and Messmate *E. obliqua*. Closed forest was present as a mid-canopy at site 5. The main species present in the closed forest was Coachwood *Ceratopetalum apetalum* (Table 2).

Table 2. Description of vegetation at systematic survey sites.

Site	Vegetation at sites from Black (2000) and Proust (2001)
1	Budderoo Plateau Forest: *Eucalyptus sieberi/Corymbia gummifera*
2	Budderoo Plateau Forest: *Eucalyptus sieberi/Corymbia gummifera*
3	Woodland: *E. piperita/Eucalyptus sieberi/Corymbia gummifera*
4	Open Forest: *Eucalyptus piperita/Eucalyptus cypellocarpa*
5	Tall open forest/Closed forest: *Eucalyptus elata/Ceratopetalum apetalum*
6	Tall Open Forest: *Eucalyptus elata/Eucalyptus cypellocarpa/ Eucalyptus obliqua*
7	Heathland: *Leptospermum subglabratum/Banksia ericifolia/ Eucalyptus dendromorpha*
8	Heathland: *Eucalyptus sieberi/Banksia paludosa/Melaleuca squarrosa*
9	Woodland: *Eucalyptus mannifera/Eucalyptus ovata/ Eucalyptus dendromorpha*
10	Budderoo Plateau Forest: *Eucalyptus sieberi/Corymbia gummifera*
11	Woodland: *Eucalyptus ligustrina* with heath
12	Budderoo Plateau Forest: *Eucalyptus sieberi/Corymbia gummifera* with heathland
13	Tall open forest: *Eucalyptus piperita/Eucalyptus sieberi/ Corymbia gummifera*

Reptile surveys

Diurnal reptile surveys were conducted at 13 sites between January and February 2002 and 2003 (Table 3). The census involved either two people surveying 0.5 hectare (50 x 100 m) for 30 mins or one person surveying the same area for 60 mins. A total of 60 mins search effort was achieved for each transect. Surveys were conducted between 08.42 and 15.28hrs EST at temperatures which ranged between 20 - 29°C during 2002, and 08.45 and 12.15hrs EST at temperatures that ranged from 22 - 28°C in 2003. The methods follow those determined by the NSW National Parks and Wildlife Service for the purpose of the comprehensive regional assessment of forests in southern NSW (NPWS, 1998).

Transects were separated by a minimum of one kilometre and located within 50 - 100 m off dirt roads or fire trails. The altitude of the sites ranged from 550 - 640 m AHD. The locations of the survey sites is given in Table 3.

Targeted surveys were conducted at additional sites such as creeklines and rock escarpments in an attempt to detect species not found during systematic surveys. In particular surveys were conducted for the Broad-headed Snake *Hoplocephalus bungaroides* on the west facing edge of the Barrengarry Creek plateau.

During herpetofauna searches, active animals were observed as they basked or foraged. Inactive animals were located by lifting loose rock, logs and decorticating bark and searching leaf litter. Animals were identified by sight and generally were not caught. Reptiles observed when travelling to and from sites or outside the survey period were recorded as opportunistic sightings and were used to collate a species list for the reserve.

Table 3. Location, survey effort and time at systematic survey sites.

Grid references in AMG 66 datum. Eastings and northings in ADG Zone 56. Altitude (Alt) in metres AHD. Survey periods are in Eastern Standard Time.

Site	Easting	Northing	Alt	2002 survey	2003 survey
1	287194	6159438	590	1253-1323hrs; 22.i.02	1130-1230hrs; 24.i.03
2	285127	6160763	560	1428-1528hrs; 30.i.02	0920-1020hrs; 23.i.03
3	286860	6165357	590	1006-1036hrs; 22.i.02	0928-1028hrs; 22.i.03
4	288724	6162427	596	1208-1238hrs; 22.i.02	1236-1326hrs; 24.i.03
5	290039	6161444	550	1427-1527hrs; 28.i.02	1438-1538hrs; 24.i.03
6	286200	6159893	610	1130-1230hrs; 14.ii.02	1031-1131hrs; 23.i.03
7	277343	6160682	610	0842-0912hrs; 16.ii.02	0921-1021hrs; 30.i.03
8	288950	6163225	620	1058-1128hrs; 22.i.02	0905-1005hrs; 25.i.03
9	287800	6161700	590	1020-1120hrs; 14.ii.02	1025-1125hrs; 24.i.03
10	282812	6162329	590	1316-1416hrs; 14.ii.02	1416-1516hrs; 29.i.03
11	283025	6161114	570	1211-1241hrs; 16.ii.02	1121-1221hrs; 30.i.03
12	288800	6163500	640	0913-1013hrs; 14.ii.02	1010-1110hrs; 25.i.03
13	277615	6160128	580	0934-1004hrs; 16.ii.02	0813-0913hrs; 30.i.03

RESULTS

A total of 153 individuals covering 11 species of reptile was observed during 22.5 hours of systematic survey (Table 4). An additional six species were detected opportunistically or during targeted surveys (Table 5). Third party observations revealed an additional species, the Death Adder *Acanthophis antarcticus*, in the area. Four species of reptile accounted for about 90% of detections: *Eulamprus heatwolei* (40%), *Lampropholis delicata* (20%), *Egernia saxatilis* (18%) and *Lampropholis guichenoti* (13%). Reptile species richness ranged from 0-4 per transect. No geckoes, blind snakes or goannas were found.

Four species were found in 2003 that had not been observed during the 2002 survey. Two of the four species were in unburnt plots. Comparing the results of 2002 and 2003, fewer reptiles were observed post fire in the burnt plots. The exception was *Eg. saxatilis*, which was detected in higher numbers post fire (11 v 16).

DISCUSSION

Effect of fire

Despite an intense fire only two species, *Pygopus lepidopodus* and *Eulamprus quoyii*, were not detected during the second survey. *Pygopus lepidopodus* and *Eu. quoyii* were rarely detected during the initial survey and the sites where they were found in the initial survey were not burnt. Hence the result is considered a reflection of their low population density or secretive habits rather than disturbance from fire. The more common and readily observed skinks were recorded in higher numbers post-fire. This finding is consistent with other studies (Braithwaite, 1984; Lunney *et al.*, 1991). Large (> 400 mm diameter) logs were observed to be burnt on their exterior but unburnt within their interior. Species that take refuge under or within large logs avoid or have reduced fire-associated mortality.

The number of individuals detected pre- and post-fire varied over the four most common species. More *Eg. saxatilis* were observed after the fire than prior to the burn. In contrast fewer *Eu. heatwolei*, *L. delicata* and *L. guichenoti* were found post-fire.

Egernia saxatilis take refuge under rocks and in the hollows and cracks of large fallen logs. The species is wary and was observed to take refuge when the surveyor/s were in close proximity (within approximately 20 m) and moving through the landscape. The majority of *Eg. saxatilis* were observed during the survey on large fallen logs in open forest and were rarely observed away from their home log. Individuals were not found at heathland sites where large logs were absent or in tall open forest where solar radiation was reduced by dense canopy. After the burn, the logs used by *Eg. saxatilis* were not obscured by dense shrubs and subsequently more lizards were seen, and as such it is not clear whether there was an impact on the population by fire.

Like *Eg. saxatilis*, *Eu. heatwolei* also take refuge under rocks and in the hollows and cracks of large fallen logs and were observed during the survey foraging a distance around large logs. *Eulamprus heatwolei* showed a marked decrease post-fire in plots that were burnt (25 v 14 individuals observed). *Eulamprus heatwolei* readily forage away from refuge logs whereas *Eg. saxatilis* are more sedentary. This difference in behaviour may explain why fewer *Eu. heatwolei* were observed in 2003 compared to the 2002 as foraging away from cover make the animals more susceptible to predation.

There was also a decline in numbers of *Eu. heatwolei* observed at unburnt sites, suggesting that factors other than fire may have had an influence on results. Lunney *et al.* (1991) found that drought markedly depressed numbers of *Eu. heatwolei*, *L. delicata* and *L. guichenoti* at Mumbulla State Forest and *Eu. heatwolei* numbers were still declining 19 months after the drought. However, data from the closest weather station (Robertson) indicate that 2003 was wetter than 2002 (1389 vs 1006 mm), suggesting that in this case a reduction in annual rainfall was not a factor.

Table 4. Number of various species of reptile observed during systematic surveys.

Top column shows site then year (2002 = 02, 2003 = 03). Bottom column: B = burnt, u = unburnt

Species	1 02	1 03	2 02	2 03	3 02	3 03	4 02	4 03	5 02	5 03	6 02	6 03	7 02	7 03	8 02	8 03	9 02	9 03	10 02	10 03	11 02	11 03	12 02	12 03	13 02	13 03	Total 2002	Total 2003
Scaly Foot																					1						1	0
Southern Water Skink	3	4			14	5	6	3	7	3		1			6	4		1					2	2			38	23
Eastern Water Skink													2												1		3	0
Black Rock Skink	1	3	3	6	2	2														3		1	5	2			11	17
Grass Skink	3	2	3	2	1	2	4	1				1	1	1	1			2			1		1		3	2	18	13
Garden Skink	3		1			3					1				2				1				1	1	3	1	12	5
Weasel Skink												5															0	5
Maccoy's Skink										2																	0	2
Small-eyed Snake																				1					1		1	1
White-lipped Snake																		1						1			0	2
Tiger Snake																						1					0	1
Total Animals	10	9	7	8	17	12	10	4	7	5	1	7	3	1	9	4	0	4	1	4	2	2	9	6	8	3	84	69
Total Species	4	3	3	2	3	4	2	2	1	2	1	3	2	1	3	1	0	3	1	2	2	2	4	4	4	2	7	9
Fire history		B		B		B		B		U		B		U		U		B		B		U		B		B		

Many species of reptile are cryptic and have patchy distributions. In general species of snake and legless lizard are infrequently found during surveys in this region and this may be a reflection of their secretive habits and low density. More species were detected post-fire but when unburnt sites are considered the species diversity over the two survey periods probably reflects search effort rather then impacts from fire.

Species richness and density

The present study recorded a total of 17 species of reptiles (11 during systematic surveys). In addition one additional species, the Death Adder, has been recorded in the park (L. Osterahus, pers. comm.). There is a possibility that the Diamond Python *Morelia spilota spilota*, Common Bluetongue *Tiliqua scincoides*, Blotched Bluetongue *T. nigrolutea*, Eastern Three-lined Skink *Acritoscincus duperreyi* and She-oak Skink *Cyclodomorphus michaeli* occur in the park, as these species have been observed within a few kilometres of the boundary.

Species assemblages, zoogeographic patterns and genetics

The absence of gekkonid and varanid lizards and typhlopid snakes was notable as species in these families have been detected about ten kilometres north in the Metropolitan Special Area of the Sydney Catchment (DECC, 2007) and ten kilometres south in Morton NP (Daly, 2006). The study area is noted as having frequent inclement weather where rain, fog and mist reduce solar radiation and saturate the shallow soils. This factor may be implicated in the absence of the Lesueur's Gecko *Oedura lesueurii*, Lace Monitor *Varanus varius* and Black Blind Snake *Ramphotyphlops nigrescens*, which are present in drier (or less misty) areas of Morton NP and the Metropolitan Special Area.

Daly (1996) states that in this region distributional data for saxicolous species of reptiles and amphibians are highly associated with sites where sandstone outcrops occur as surface rock. The results of this survey concur with this finding. Saxicolous herpetofauna utilise various formations of a common sandstone substrate along the Illawarra escarpment from Morton NP to the Metropolitan Special Area of the Sydney Catchment. The limited area for dispersal along the sandstone escarpment north and south of Budderoo NP combined with the low temperatures and inclement weather suggest a real barrier for dispersal and hence genetic flow for many saxicolous species.

Recent phylogenetic studies have indicated that populations of *H. bungaroides* comprise two genetically divergent clades that correspond to distinct regions north and south of approximately Wollongong (Sumner *et al.*, 2009). We suggest that the division of these clades is between the sandstone outcrops of the Metropolitan Special Area of the Sydney Catchment and Morton NP. These populations are isolated by the presence in the intervening area of volcanic soils associated with the Robertson flow, and the climate at Barren Grounds and Budderoo, which are often covered in mist or cloud.

Hoplocephalus bungaroides take refuge under loose west-facing rock on rock microhabitats that are dry, receive a large degree of solar radiation and lack earth or organic debris (Webb & Shine, 1998; Daly, 2006; Croak *et al.*, 2008). This habitat is largely absent in the area between Barren Grounds and the Sydney Catchment and the volcanic intrusion has resulted in some areas where the sandstone is reduced to a thin area of the escarpment and fallen talus. *Hoplocephalus bungaroides* would have to disperse along the sandstone escarpment and the wet and often cold heath and woodlands of Barren Grounds and Budderoo. We suggest that these factors are responsible for the northern and southern populations being isolated for the approximately 755,000 - 850,000 years indicated by Sumner *et al.* (2009).

No *Hoplocephalus bungaroides* were detected during this survey, despite targeted surveys. The exfoliated rock habitat associated with this species was present but restricted

Table 5. Species of reptile recorded in Budderoo National Park

Detection: s = observed during systematic surveys, o = observed opportunistically, oa = observed adjacent to the reserve, I – Mr L. Osterahus pers. comm.

Family	Species	Common name	Detection	Wildlife Atlas records
Pygopodidae	*Pygopus lepidopodus*	Scaly Foot	s	
Agamidae	*Amphibolurus muricatus*	Jacky Dragon	o	x
	Physignathus lesueurii howitti	Gippsland Water Dragon	o	
	Physignathus lesueurii lesueurii	Eastern Water Dragon		x
Scincidae	*Acritoscincus platynota*	Red-throated Skink	o	x
	Egernia saxatilis	Black Rock Skink	s	x
	Eulamprus heatwolei	Southern Water-skink	s	x
	Eulamprus quoyii	Eastern Water-skink	s	x
	Lampropholis delicata	Grass Skink	s	x
	Lampropholis guichenoti	Garden Skink	s	x
	Nannoscincus maccoyi	Maccoy's Skink	s	
	Saproscincus mustelina	Weasel Skink	s	x
Elapidae	*Acanthophis antarcticus*	Death Adder	I	
	Austrelaps ramsayi	Highland Copperhead	oa	
	Drysdalia coronoides	White-lipped Snake	s	x
	Hemiaspis signata	Swamp Snake	o	x
	Notechis scutatus	Tiger Snake	s	x
	Pseudechis porphyriacus	Red-bellied Black Snake	o	x
	Rhinoplocephalus nigrescens	Small-eyed Snake	s	x
		Total Species	18	

in distribution. The presence of *O. lesueurii* is not considered a pre-requisite for the occurrence of *H. bungaroides* as *H. bungaroides* has been detected in the southern portion of Morton NP where *O. lesueurii* is absent (Daly, 2006).

CONCLUSIONS

This study has allowed us to compile a species list of reptiles that occur within the park. The use of fixed time/length transects provides data that can quantify changes in abundance of common species of reptile, provided sufficient replicates are available. However, many species were observed opportunistically or in special habitats not assessed during the transect surveys and a combination of techniques is necessary to derive a comprehensive species inventory. Multiple repeat surveys and/or a higher number of survey sites would be necessary before any definitive conclusion can be made about changes to population densities in relation to fire.

The geology of the area has resulted in a bottleneck of suitable habitat for saxicolous species of herpetofauna to use for dispersal north and south of Budderoo NP. This has implications for the conservation of species as the genetic results for *Hoplocephalus bungaroides* suggest that other rock-loving reptiles many be similarly genetically fragmented.

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A MATING AGGREGATION OF OLIVE PYTHONS, *LIASIS OLIVACEUS*, WITH COMMENTS ON MATING SYSTEMS AND SEXUAL SIZE DIMORPHISM IN SNAKES

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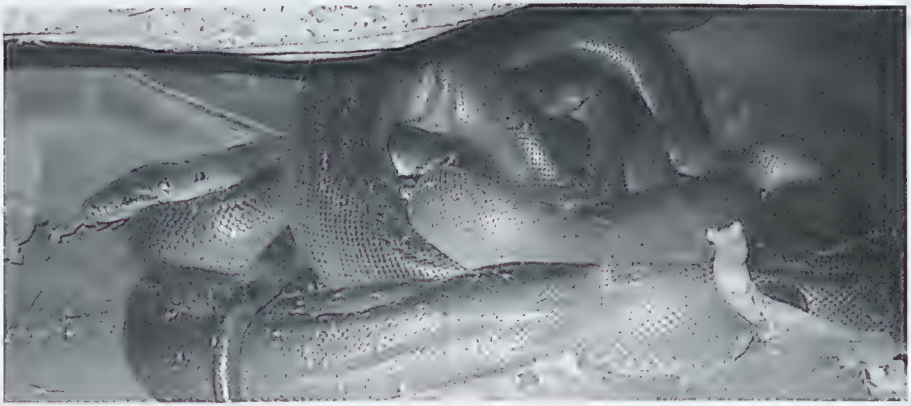
INTRODUCTION

In some animals multiple males aggregate around a single female in an attempt to mate with her. The occurrence of such aggregations can often help clarify the mating systems of species (Schuster & Wade, 2003). In snakes, these 'mating ball' aggregations may also contribute to our understanding of factors underpinning sexual size dimorphism (SSD) (reviewed in Rivas and Burghardt, 2001). However, there are relatively few reports of this behaviour in nature, hindering our ability to explore potential links between behaviour, mating systems, and SSD. Mating aggregations have been observed in several species including *Eunectes murinus* (Rivas & Burghardt, 2001), *Laticauda colubrina* (Shetty & Shine, 2002), *Acrochordus arafurae* (Worrell, 1963; Shine, 1986), *Natrix natrix* (Madsen & Shine, 1993), *Nerodia cyclopion* and *N. sipedon* (Mushinsky, 1979), *N. fasciata* (S. Doody, pers. obs.), *Regina grahamii* (Anderson, 1965), *Seminatrix pygaea* (Gibbons & Dorcas, 2004), *Thamnophis marcianus* (Seigel *et al.*, 2000), *T. butleri* (Finneran, 1949) and *T. sirtalis* (Gardner, 1955, 1957). Herein we present the first reported occurrence of a mating ball in the olive python, *Liasis o. olivaceus*. We briefly discuss the relevance to previous reports of male combat in the species, and SSD in snakes.

OBSERVATIONS

In late afternoon on 15 August, 2005, we located three olive pythons coiled together underneath a pile of scrap metal in open woodland along the Daly River near Oolloo Crossing (14°04'20"S 131°05'16"), Northern Territory (Figure 1). The snakes were approximately 70 m from the river, and about 10 m

Figure. 1. Olive Python (*Liasis olivaceus*) mating aggregation ball under scrap metal. The head of the third snake is not visible. Photograph by C. Davies.



from thicker riparian vegetation. We captured, sexed, and measured the snakes, and released them at the site of capture the following day. There were two males (SVL = 286.5 cm, 295.4 cm; TL = 31.0 cm, 44.4 cm; mass = 7.18 kg, 5.91 kg) and one female (SVL = 292.0 cm; TL = 40.6 cm; mass = 6.54 kg).

DISCUSSION

Mating aggregations and male combat

Our observation of two male pythons intertwined around a female snake suggests mating. Although we did not observe copulation, we can think of no other reason for the aggregation. Consistent with this idea, *L. olivaceus* reproduces during the dry season, although the exact timing of mating is unknown (Shine & Slip, 1990). To our knowledge mating aggregations have not been reported in *L. olivaceus*.

There are two types of mating phenomena reported in snakes: mating aggregations, with multiple males competing for and entangled with a single female, and male combat, where two males 'fight', presumably to gain access to a nearby female. Our observation of a mating aggregation in *L. olivaceus*, coupled with observations of male combat in *L. olivaceus* in captivity (Ross & Marzec, 1990; Barker & Barker, 1994) suggests that these behaviours may not be mutually exclusive within populations. The only other snake for which both behaviours have been reported is the carpet python *Morelia spilota*: Shine and Fitzgerald (1995) found mostly combat in northern populations, but only aggregations in southern and inland populations, although inland populations have been reported to exhibit combat by Pearson *et al.* (2002a).

Shine and Fitzgerald (1995) contended that these mating behaviours were not phenotypically plastic responses to local environmental conditions. Rather, they suggested a strictly genetic basis to these traits, based on a cited personal communication regarding the persistence of the 'behaviour of origin' after long periods in captivity. Indeed, there is little evidence for the co-occurrence of these behaviours within a population. The authors reported two cases of aggregations in a population of *M. spilota* known to engage in male combat, and noted bite scars on two males in one aggregation. The paucity of observations of combat and aggregations makes their claim premature, because the likelihood that both behaviours would be reported in the same population is very low due to the rareness of observing either. We hypothesize that both mating aggregations and male combat are in the mating repertoire of each individual snake, and are context-dependent.

Mating behaviours and sexual size dimorphism

Male combat has been reported in other python species (Shine, 1978; Lloyd & Fearn, 2005), and has been proposed as an explanation for the evolution of male-biased sexual size dimorphism (SSD) in snakes, leading to the prediction that species or populations engaging in male combat will tend to exhibit male-biased SSD, while species not engaging in combat will exhibit no SSD or female-biased SSD (Shine, 1994; Pearson *et al.*, 2002b). Mating aggregations seem to generally involve female-biased SSD, although a quantitative review is lacking.

The snakes in our mating aggregation were similar in size, and Shine and Slip (1990) found little difference in body size between the sexes in *L. olivaceus* museum specimens (mean SVL: males = 175.9 cm, n = 23; females = 190.1 cm, n = 24). However, because SSD may vary among populations (Shine & Fitzgerald, 1995; Pearson *et al.*, 2002b), we measured 42 live adult *L. olivaceus* (n = 28 males, 14 females) from roads in the area where the mating ball was found (Douglas-Daly region). Snakes were classified as adults when males were > 100 cm, and when females were > 108 cm (after Shine and Slip, 1990). Neither SVL nor mass differed significantly between males and females (single-factor ANOVA: SVL: $F_{1,41}$ = 0.322, p = 0.573; mass: $F_{1,40}$ = 0.08, p = 0.783), confirming little or no SSD in the population, and possibly in the species.

In summary, the co-occurrence of mating aggregations and male combat in *L. olivaceus* and *M. spilota* serves as a reminder that there is a need to clarify the relationships among mating aggregations, male combat, and SSD in snakes. Do aggregations and combat occur in the same population, or are aggregations and combat generally mutually exclusive within populations? The former scenario suggests that mating systems and SSD are either independent, or that SSD precedes mating tactics, rather than these behaviours driving the evolution of male body size and thus, SSD. Further observations, along with experiments with captive animals, would help to answer these questions.

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NATIVE GECKO INTRODUCTIONS

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The ability of an organism to colonise a new area can only be described as a successful attribute for survival of the species. Whether we like or not, Australia's short modern history is founded on countless purposeful or inadvertent human introductions of plants and animals (Low, 2002). Among the reptiles, geckos are regularly dispersed via human cargo and vessels, and are often recorded in the literature as inadvertent introductions. In Australia, the two most successful colonisers across the tropical North are the Asian House Gecko, *Hemidactylus frenatus* (Fyfe, 1981; Cook, 1990; Lloyd, 2000; Maryan, 2001; Michael, 2005; Hollis, 2006; Lemckert, 2007), and the Mourning Gecko, *Lepidodactylus lugubris* (Limpus *et al.*, 1999; McKay & Horner, 2007). The continuous dispersal and subsequent establishment of these two 'naturalised exotics' is well documented in Australia. By comparison, native Australian gecko species are rarely recorded as dispersing beyond their native range with the aid of humans. Messenger (2005) reports *Gehyra dubia* becoming established on Heron Island and Cogger (1992) refers to the Alice Springs population of *Oedura rhombifer* as being introduced; however, Couper *et al.* (2007) suggest this population may be naturally occurring owing to its morphological distinctiveness.

In this paper I report observations of two Australian gekkonine species, one arboreal and one terrestrial, which have established populations distant to their natural distributions. *Gehyra australis* is a common house gecko across northern Australia where it often lives alongside *H. frenatus* (pers. obs.). *Heteronotia binoei* is found over most of Australia and is the most abundant reptile in many areas (Wilson & Swan, 2003).

In September 2008, numerous immature and adult *G. australis* were observed active at night on the ablution blocks at the Lighthouse Caravan Park (21°48'31"S 114°06'54"E) near Exmouth. Two adults were subsequently captured, identified as *G. australis* based on their large size and undivided subdigital lamellae, and lodged with the Western Australian Museum (R134405, R134629). It is interesting that *G. australis* has become established in a relatively remote location on the North West Cape that is substantially further south than the nearest naturally occurring populations, at Dampierland in the southwest Kimberley (pers. obs.), over 1000 km to the north-east. A single *Hemidactylus frenatus* was also observed at the Lighthouse Caravan Park. *Gehyra australis* and *H. frenatus* have not been previously recorded on the North West Cape (Storr & Hanlon, 1980; Storr *et al.*, 1990). Other populations of *G. australis* that are less distant from their natural distribution occur on buildings in northwestern Queensland (M. Hutchinson, pers. comm.). One colony is at the government agriculture research station ('Toorak') located 30 km south of Julia Creek (21°03'S 141°49'E) and another occurs alongside *H. frenatus* at the Barkly Roadhouse (20°28'S 138°28'E). One can only speculate on how the native *G. australis* arrived at these locations distant from their natural distribution or how long they have been established. However, given the distance from natural populations, and the occurrence of these populations at human settlements, it is highly likely that they were dispersed by anthropogenic activities, although it appears to be less successful at establishment than *H. frenatus*, which has established itself in coastal Pilbara towns such as Karratha and Port Hedland (pers. obs.) where *G. australis* seems to be absent, or at least poorly documented at this stage. The repeated observation of *H. frenatus* (and now *G. australis*) at roadhouses and other tourist venues, distant from towns and cities, suggests that the pathways of dispersal for geckos have been enhanced by tourist activity, particularly caravan groups travelling around the country. Adding to this the constant interstate and intrastate transfer of freight via road

and rail, it is not surprising that small reptiles, such as arboreal and widespread geckos, are dispersed to distant locations.

Heteronotia binoei is naturally absent from the lower southwest of Western Australia (Storr *et al.*, 1990), although it was later included by Bush *et al.* (1995) as present there, based on an introduced population at Buckland Hill in the Perth suburb of Mosman Park (32°01'S 115°46'E). At this location it was relatively common in December 1985 under limestone rocks and rubbish. Another population was located in December 2005 in an industrial zone at Fremantle (32°04'S 115°45'E) where numerous juveniles and adults were found under rubbish. Single adults from both locations have been lodged with the Western Australian Museum (R93697, R156991). Both locations have since undergone rapid housing development and the populations may no longer exist at the original sites. It is not known how widespread *H. binoei* is in the surrounding area or whether they include all-female parthenogenetic races. Future surveys are planned in the area to determine the extent of their dispersal.

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PREDATION OF HYLID FROG SPAWN BY LEPTOCERID CADDISFLY LARVAE (INSECTA:TRICHOPTERA) AT EUNGELLA NATIONAL PARK, CENTRAL-EASTERN QUEENSLAND

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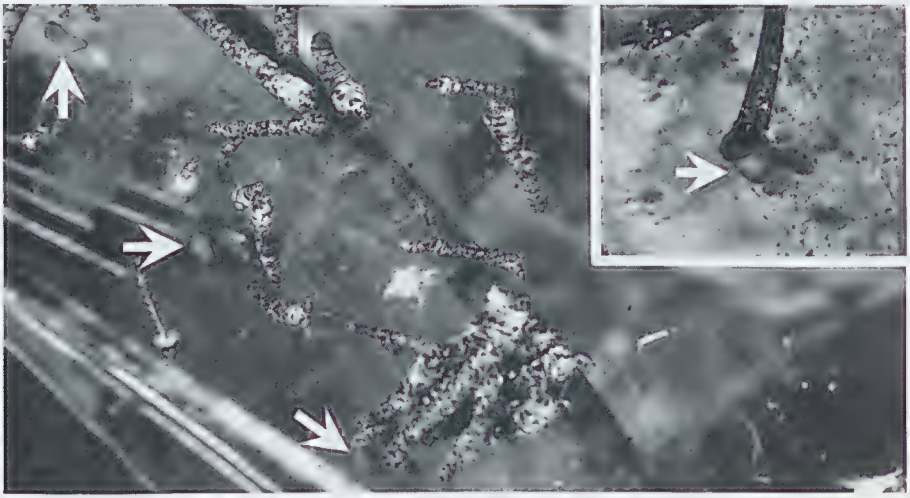
INTRODUCTION

Egg predation by caddisfly larvae (Insecta: Trichoptera) is a significant cause of embryonic mortality amongst North American and European amphibian species (Rowe *et al.*, 1994; Richter, 2000 and references therein). In Australia, however, reports of egg predation by caddisfly larvae are rare (St Clair, 1994) and the impact of such predation on recruitment in Australian amphibian species is largely unknown. Here I report the predation of hylid frog spawn by leptocerid caddisfly larvae at Eungella National Park, eastern Queensland, and comment on the likely impact of egg predation by caddisfly larvae on recruitment of affected frog species.

OBSERVATIONS

The observations reported here were made whilst surveying and monitoring stream frogs in rainforest at Eungella National Park, central eastern Queensland, between January 2000 and January 2005. During this time, large-scale localized predation of frog spawn by caddisfly larvae was observed twice: once in late November 2001 and again in October of 2004. On 28 November 2001, large numbers of caddisfly larvae were seen feeding on freshly-laid spawn of the southern orange-eyed treefrog (*Litoria chloris*) in stream-side pools along an unnamed tributary of Cattle Creek, at around 700 m elevation (21°03'23"S 148°35'19"E). Along this stream, caddisfly larvae were seen chewing through the jelly matrix surrounding

Figure 1. Caddisfly larvae feeding on *Litoria* spawn at Mt William Creek, Eungella National Park. Most of the embryos within the egg mass appear to have been consumed by caddis fly larvae, leaving only the surrounding jelly matrix. The few embryos remaining within the jelly matrix are highlighted with arrows. Inset: close up of a caddisfly larva consuming a developing embryo (highlighted with an arrow) in a separate egg mass at Mt William Creek.



L. chloris eggs and consuming the early stage embryos within. At the time, few embryos appeared to have been eaten by caddisfly larvae. However, given the number of caddisfly larvae present (dozens per egg mass) mortality amongst developing embryos would doubtless have been significant. On 22 October 2004, caddisfly larvae were seen massing over spawn of both *L. chloris* and the whirring treefrog (*Litoria revelata*) in streamside pools along Mt William Creek, a tributary of Cattle Creek, at around 900 m elevation (21°01'39"S 148°36'11"E) (Gosner stage 16-17 embryos of *L. revelata* were distinguished from sympatric *L. chloris* embryos by their darker colour [see Anstis, 2002]). As before, larvae were seen chewing through the jelly matrix surrounding developing embryos and feeding on embryos encapsulated within the jelly matrix (Figure 1). In this instance egg capsules within the submerged egg mass were mostly empty. With no hatchling larvae or any other predatory species present in pools, the presence of empty capsules could only be attributed to predation by caddisfly larvae.

Caddisfly larvae feeding on frog spawn at Eungella National Park were collected and preserved in 70% ethanol for subsequent identification. Specimens collected from Eungella were later identified as leptocerid caddisfly larvae (Trichoptera: Leptoceridae) by staff at the Queensland Museum.

DISCUSSION

Leptocerid caddisfly larvae are known to feed on a range of plant and animal matter including frog spawn (CSIRO, 1991; St Clair, 1994).The significance of egg predation by leptocerid caddisfly larvae or any other caddisfly larvae, on native Australian anuran species, however, is largely unknown.

Studies outside of Australia have shown predation by caddisfly larvae can result in significant mortality amongst amphibian eggs and embryos where caddisfly larvae occur at high densities (Rowe *et al.*, 1994; Richter, 2000). The observations reported here indicate predation by caddisfly larvae can result in significant mortality of *L. chloris* and *L. revelata* eggs/embryos where densities of larvae in stream-side pools, habitat frequently utilized for breeding by these species at Eungella (Hero *et al.*, 1996; pers. obs), are high. At the time observations were made, densities of caddisfly larvae in stream-side pools appeared unusually high. At other times and elsewhere in Eungella National Park densities of larvae appeared much lower and predation of frog spawn was not observed, despite the regular presence of spawn in streamside pools. Predation of hyild frog spawn resulting in significant embryonic mortality therefore appears to be rare at Eungella.

Though the paucity of records of egg predation by caddisfly larvae in Australia suggests such predation is rare in Australian frog species, it is possible that predation by caddisfly larvae in Australia is under-reported. Additional observations and research are needed to determine whether or not this is actually the case and to determine the extent to which caddisfly predation might impact recruitment in native frog species.

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A RECENT RECORD OF THE ENDANGERED SKINK *ANOMALOPUS MACKAYI* AND A DESCRIPTION OF ITS HABITAT

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Anomalopus mackayi is a medium-sized skink that has a restricted national distribution, occurring in a small area of north-eastern New South Wales and south-eastern Queensland (Sadlier & Pressey, 1994; Wilson & Swan, 2008). The species lives in permanent deep tunnel structures and deep soil cracks using fallen timber and other surface debris as shelter sites (NPWS, 1999). Generally, *A. mackayi* have been recorded within open woodland with moist black soil (Swan *et al.*, 2004) and open grasslands on heavy cracking soil (Wilson, 2005). However, there have been some exceptions. A single specimen north of Oakey, Queensland was found under a railway sleeper on sandy soil (S. Wilson in Cogger *et al.*, 1993) and in another instance, a single specimen was found in cleared woodland near granite outcrops (Shea *et al.*, 1987) suggesting broader habitat preferences, and that more information on the habitat of this species is needed.

There are few records of *A. mackayi* (14 in NSW) with only a handful of these occurring in the past 40 years (DECC, 2009). Across their range, records are centred on the Oakey and Dalby regions in Queensland and the Wallangra, Mungindi and Wee Waa regions in New South Wales. With little natural vegetation remaining within its known range due to clearing, the majority of records older than 40 years and more recent searches in the same locations unsuccessful, Shea *et al.* (1987) suggested that the species was very rare and likely to become endangered. Determinations by Scientific Committees have now listed *A. mackayi* as Endangered under the NSW Threatened Species Conservation Act 1995 (TSC Act), Vulnerable under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999, and Endangered under the Queensland Nature Conservation Act 1992. This short note documents a recent record of *A. mackayi* and includes a description of the habitat where the specimen was recorded.

One *A. mackayi* was found within the crevices of a fallen log on 14 October 2008 near Bellata, in northern New South Wales. The general landscape around Bellata is characterised by extensive clearing for agricultural activities where generally only small isolates of remnant vegetation remain. This site was no different, being a small, isolated Myall Woodland remnant of less than 5 ha in area (29°36'S 149°49'E). The individual quickly retreated to the loose soil after it was disturbed during the hand search of fallen timber, where it was captured and identified. The animal was located after approximately two person hours of searching. Despite additional searches that day over three person hours and the following day for an additional three person hours, in both the remnant and surrounding area, no further individuals were located. Due to its subterranean habits, the detection of only one *A. mackayi* is not surprising despite this level of search effort.

Anomalopus mackayi was known to occur at Bellata and in the wider region previous to our record. Searches of the NSW Atlas of NSW Wildlife reveal one record at Bellata in December 1992, one record 40 km to the south-west in April 1976, one record 20 km

to the north-east at Terry Hie Hie in March 2001 and one record around 30 km to the north-west in March 1999 (DECC, 2009).

The Myall Woodland remnant was situated on a moist deep cracking brown-black soil and was characterised by an overstorey of Boree *Acacia pendula* with scattered Mimosa Bush *Vachellia farnesiana* and Emu Bush *Eremophila* sp. The noxious weed African Boxthorn *Lycium ferocissimum* was also present in small numbers. Closer to a drainage line that flanked the site, Black Tea-tree *Melaleuca bracteata* dominated. The understory had a variety of native and exotic flora species present. The native species observed included Kangaroo Grass *Themeda australis*, Dwarf Darling Pea *Swainsona luteola*, a Nightshade *Solanum* sp., Black Rolypoly *Sclerolaena muricata*, Spear Grass *Austrostipa* sp., Windmill Grass *Chloris truncata*, Bluebell *Wahlenbergia* sp. and Twinleaf *Zygophyllum* sp. The exotic species observed included Field Mustard *Brassica rapa*, Ryegrass *Lolium* sp., Common Sowthistle *Sonchus oleraceus*, African Lovegrass *Eragrostis curvula*, Caster Oil Plant *Ricinus communis* and New Zealand Spinach *Tetragonia tetragonioides*. Characteristics of the ground cover attributes were noted (60% native flora, 15% exotic flora, 5% fallen timber, 20% bare ground), however, no specific data was collected on height of the ground flora. It is estimated that the average height of this vegetation was approximately 20 cm. Despite the remnant having many exotic plant species, no evidence of soil cultivation or recent grazing was observed. The vegetation community of this remnant, Myall Woodland, is also listed as an Endangered Ecological Community under the TSC Act.

This recent record of *A. mackayi* demonstrates the importance of small woodland remnants in agricultural dominated landscapes to maintain regional biodiversity and that further target surveys should be undertaken across other small woodland remnants to greater understand the current status and habitat requirements of this species in NSW.

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AN OBSERVATION OF COPULATION IN THE BARRED TREE SKINK, *EMOIA TROSSULA* BROWN & GIBBONS, 1986 (SQUAMATA: SCINCIDAE) IN TONGA

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The reproductive biology of the skinks of Pacific Oceania is poorly known, and copulatory behaviour even more so (Greer, 1989). Among these species is the semiarboreal Barred Tree Skink, *Emoia trossula*, first described from Fiji and Rotuma (Brown & Gibbons, 1986), and subsequently reported from Tonga and the Cook Islands (Crombie & Steadman, 1988; Gill, 1990; Gill & Rinke, 1990; Brown, 1991; Steadman *et al.*, 1999).

The only previous published data on reproduction in this species were by Zug (1991), who reported gravid females carrying 2-3 eggs in April (Yadua Taba, Fiji) and May (Rotuma).

On 4 March 2009, one of us (KS) observed a mating pair of *Emoia trossula* on the deck of their house in Toula, Vava'u, Tonga (18°40'S 173°58'W) (Figure 1). The species identity was confirmed by GS based on the characteristic pattern of irregular transverse black bars and narrow pale streaks dorsally on an olive-brown ground colour (Gill, 1990; Brown, 1991). The only other large *Emoia* reported from Tonga are *Emoia tongana* (previously *E. murphyi*; Austin & Zug, 1999), *Emoia nigra* (Gill & Rinke, 1990) and *Emoia adspersa* (Gill *et al.*, 1994). The latter species is as yet only known from Niuafo'ou (Gill *et al.*, 1994), *E. nigra* was only recorded from

Figure 1. Mating pair of *Emoia trossula*, photographed on deck of house. (Photo: K. Stone).

Niuafo'ou and Niualoputapu by Gill and Rinke (1990), and all three species have very different colour patterns to *E. trossula*.

Although the skinks were not captured and handled to confirm the sexes, the behaviour observed was typical of lizard copulation, with one skink (the presumed male) biting the other (the presumed female) on the forebody, and curling its tail under the cloaca of the other. The bite position was just behind the forelimb of the female, and in curling his body and tail base under the female's cloaca, the male used one hind limb to grip over the female's tail base. The observed duration of copulation was approximately one minute.

The timing of our observation is consistent with Zug's (1991) observation of gravid females of this species between April and May, and supports the view that reproduction of this species occurs in autumn, towards the end of the summer wet season, although data from outside this period are needed to confirm this.

Emoia is a member of the *Eugongylus* group of lygosomine skink genera, distributed over Australia, New Zealand, Indonesia, New Guinea and Oceania (Greer, 1979). Within this group, which consists of 33 genera and 328 species, direct observations of copulation have only previously been reported for *Emoia longicauda* (Millen, 1976, as *E. cyanogaster*), three species of *Carlia* (Wilhoft, 1963; Whittier, 1993; Langkilde & Schwartzkopf, 2003; Lane, 2006), *Cryptoblepharus cygnatus* (Horner, 2007), two species of *Lampropholis* (Traill, 2001; Shine & Shine, 2002), *Oligosoma otagense* (Watchman, 1979) and *Pseudemoia entrecasteauxii* (Stapley, 2008). Given Traill's observation of a single female in the midst of a mass of entwined male *Lampropholis guichenoti* with some copulation occurring, it is likely that the balls of entwined *Lampropholis* species previously observed by Cogger (1967), Griffiths (1987) and Ehmann (1992) also represent copulation events. The photograph of two entwined *L. delicata* provided by Daly (1993), interpreted as fighting, may also represent attempted copulation, as the individual wrapping around the other appears to have a partly extruded hemipenis, and the bite position is just behind the forelimb. All of these species, other than the New Zealand *Oligosoma*, are from Australia. Even more remarkably, only five of these previous reports are accompanied by photographs (Millen, 1976; Griffiths, 1987; Whittier, 1993; Daly, 1993; Horner, 2007).

The position of the mating bite, just behind or above the forelimb, and the gripping of the female's tail base by the apposed hind limb of the male, are consistent features of all of these reports when such detail is mentioned, and suggest that this copulatory position is widespread in the *Eugongylus* group, despite the variation in body shape between the short, wide bodies of *Carlia* species and the more elongate and supple body of *Emoia trossula*. While Lane (2006) reported the tail of the male undulating in front of the female's head in her single observation of copulation in *C. rubrigularis*, our observation, as well as those of Millen (1976), Whittier (1993) and Horner (2007) show a variety of tail positions, all reflecting strong flexion of the tail base across and below the female's cloaca. Other aspects appear to be variable among species. The mating "balls" of *Lampropholis* appear to be unique to that genus, as does Stapley's (2008) observation that in *Pseudemoia entrecasteauxii*, the bite is released once the hemipenis is inserted.

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HOW SPECIALISED IS THE DIET OF THE BANDY-BANDY, *VERMICELLA ANNULATA*?

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Vermicella annulata is a secretive nocturnal species, widespread in eastern Australia. It is usually encountered on roads at night or uncovered from beneath logs or rocks.

There are numerous literature accounts of this species feeding exclusively or primarily on Blind Snakes (Typhlopidae) (Worrell, 1963; Wilson & Knowles, 1988; Shine, 1980, 1991; Keogh & Smith, 1996; Cogger, 2000; Storr *et al.*, 2002; Wilson & Swan, 2008), although several authors suggest that it also takes lizards (McPhee, 1968; Gow, 1989; Mirtschin & Davis, 1992; Ehmann, 1992). Kinghorn (1964) stated that food consisted of large insects, frogs, small lizards and snakes, while Frauca (1982) stated that it had fed on termites in captivity.

Williams (1992) reported on the diet of four Bandy-bandies in captivity. All ate *Ramphotyphlops* spp. (93 between them). One also ate two pygopodid lizards (*Delma inornata*), three consumed at total of five fossorial skinks, *Anomalopus lentiginosus* (now *A. leuckartii*), and one ate two surface-active skinks, *Ctenotus robustus*. A range of other skink and pygopod species was offered but not taken.

There is also a confirmed record of attempted predation on a small elapid snake. A Bandy-bandy (J40324) is lodged in the collection of the Queensland Museum, having died in captivity consuming a Golden-crowned Snake (*Cacophis squamulosus*) (Figure 1).

Figure 1. Bandy-bandy and Golden-crowned Snake

We report here two separate instances of the Coral Snake (*Brachyurophis australis*) as a prey item of Bandy-bandies under atypical conditions in the field.

Work on a 217 km gas pipe line in Queensland's Southern Brigalow Belt between Kogan and Wallumbilla involved the removal and relocation of animals found in the open trench. Among those recorded were 14 Bandy-bandies, 36 Blind Snakes of four species and 22 Coral Snakes.

On the morning of 13 January 2009 a Bandy-bandy 69 cm in total length was found trying to burrow into loose soil that had collapsed into the trench. The snake was removed, bagged and taken into adjacent Callitris/ironbark woodland for release. On removal from the bag at the point of release it was noticed that something was protruding from the snake's mouth. Closer inspection showed this to be the tail of a snake. The Bandy-bandy was placed on the ground where it regurgitated a freshly killed Coral Snake (Figure 2). When this was completed it also regurgitated a Blind Snake (*Ramphotyphlops proximus*) (Figure 3). The Coral Snake measured 30.5 cm in total length and the Blind Snake 29 cm.

Later that day a dead Bandy-bandy was found in the trench. It appeared that this snake was in a sunlit area of trench and had been unable to reach cover. This Bandy-bandy was 43.9 cm long and next to it was a regurgitated Coral Snake 28.5 cm long.

Because the three prey items showed no sign of decomposition or tissue breakdown from

Figure 2. Bandy-bandy regurgitating a Coral Snake.

gastric juices it was surmised that they were probably killed and eaten the previous night in the trench.

McPhee (1968) stated that captive specimens have eaten "small skinks mainly of the burrowing variety" and Ehmann (1992) commented that "it is also known to take long-bodied burrowing skinks". Williams (1992) however, appears to provide the only record specifying actual lizard species eaten by captive Bandy-bandies.

It seems reasonable to assume that under normal circumstances, typhlopids still comprise the primary diet of *V. annulata* (Keogh & Smith, 1996). They remain the only recorded prey items in wild-caught Bandy-bandies. However, predation on other reptiles under atypical conditions such as in captivity or confinement within a pipeline trench provides an insight into the range of other potential prey items that could occasionally be consumed by Bandy-bandies under natural conditions.

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Figure 3. Bandy-bandy with regurgitated Coral and Blind Snakes.

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FIELD OBSERVATIONS OF MALE COMBAT IN BROWN TREE SNAKES *BOIGA IRREGULARIS* (COLUBRIDAE) FROM NORTH QUEENSLAND.

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ABSTRACT

Four separate instances of male combat and pursuit in wild Brown Tree Snakes *Boiga irregularis* from the Wet Tropics region of north Queensland are described. This is the first documented occurrence of combat in wild *B. irregularis*. The presence of male combat in *B. irregularis* is consistent with the trend for this behaviour to occur in snake species where males are larger than females.

INTRODUCTION

The Brown Tree Snake *Boiga irregularis* is a common arboreal and nocturnal colubrid that is native to tropical northern and eastern Australia, Indonesia, Papua New Guinea and the Solomon Islands (Worrell, 1963: 105; Cogger, 2000: 619; Rodda & Savidge, 2007). It is one of the most intensively studied snakes in the world owing to its accidental introduction to the Pacific island of Guam and the resultant devastating effect on the island's avifauna (Savidge, 1987; Rodda *et al.*, 1999a). Despite this, it is apparent that many aspects of the species' behaviour in the wild and reproductive biology (Savidge *et al.*, 2007) remain poorly known, particularly in the Australian populations. For example, Shine (1991a: 121) states that no Australian colubrids exhibit male combat 'but it would not be surprising to find it one day in brown tree snakes or slatey-grey snakes, the only Australian colubrids in which males grow larger than females'. Male combat has since been reported in Slatey-Grey Snakes *Stegonotus cucullatus* (Brown *et al.*, 2002) but not as yet in wild *B. irregularis*. We report four separate occurrences of male combat in wild *B. irregularis* from north Queensland.

OBSERVATIONS

Three observations (1–3) were directly observed by us and a fourth consisted of an amateur video of a combat bout recorded by a local resident. Observation 1 occurred at a residence in Buttegieg Road, Babinda (17°21'S 145°55'E; 21 m asl) when one of us (BJ) was called to remove nuisance snakes from an old cane-cutter barracks. This residence was surrounded by rainforest on three sides with the Russell River approximately 50 m away. Observations 2 and 3 occurred at one of the authors' (GT) residence at Upper Daradgee (17°32'S 145°55'E; 40 m asl), 18 km west of Innisfail, in a house surrounded by rainforest near Coccolah Island on the North Johnstone River. Several adult *B. irregularis* were known to be resident in and around the house where during the cooler months they sought refuge in the ceiling and in a carport/shed adjoining the house. At other times of year they were typically sighted along the junction between the walls and eaves (where there is a gap into which they could retreat) and also on the roof battens/rafters along the veranda. One adult male *B. irregularis* had been resident for at least six years and was sighted several times each year; this male features in observations 2 and 3 below and was readily identified by its colouration and head markings. At least five other transient *B. irregularis* were sighted over this time. Observation 4 occurred at a residence in Stager Road, Babinda. It consists of 12 minutes of video that was filmed in two segments on the same evening and involved two (presumed) males in combat with a third adult nearby (presumed female). We viewed the video and describe its contents below.

The sex of snakes in the observations was determined by three methods: eversion of hemipenes (observations 2 and 3 below), probing (observation 1) and examination of the tail-base (all observations), which in males was noticeably swollen. The latter method is, however, known to be unreliable, particularly in males (Jordan & Rodda, 1994). The snout-to-vent length (SVL) was measured (to the nearest 0.05 m) in only some snakes.

Observation 1. 3 September 2002, approx. 7:30 pm.

When I (BJ) arrived at the residence I found two adult male *B. irregularis* (SVL 1.60 m and 1.75 m; both probed to a depth of about 25 mm) entwined and hanging vertically from the eaves; a further 3 m along the eaves was a female (SVL 2.0 m; probed to a depth of about 10 mm) lying parallel to the roof guttering with about 0.3 m of the head and anterior body hanging over the guttering. Approximately three-quarters of the males bodies were tightly plaited. Their heads and anterior bodies were aligned one above the other in a U-shaped configuration and they were pushing against each other; their tails and vents were clearly separated and wrapped around a wooden beam. About 5 m away, and around the corner of the building on the carport roof, were another two (presumed male) *B. irregularis* (SVL 1.50 m and 1.65 m; not probed) entwined in a similar posture. All snakes were removed and relocated to nearby rainforest.

Observation 2. 25 August 2005, 9:20 pm, 19°C, RH 80% with intermittent rain.

Between about 8:30 - 9:20 pm I (GT) heard noises on the roof which I attributed to the activity of Giant White-tailed Rats *Uromys caudimaculatus* which are common in the area. The noises shifted location but were quite different to those usually associated with the rats, consisting of what sounded like something sliding along the iron roof interrupted by occasional loud 'thuds'. I caught sight of some movement after a 'thud' occurred outside the kitchen window and

Figure 1. Two male Brown Tree snakes *Boiga irregularis* in combat (see Observation 2).

went to investigate. I observed two adult male *B. irregularis* both of similar size (approx. 2.0 - 2.2 m total length), hanging down vertically from a roof batten at the top of the wall and tightly plaited along the posterior half of their bodies (Figure 1). One of these was the resident male (it was the larger of the two) while the other was a male that had been relocated from a residential area about a year earlier (indicated by the presence several anomalous dorsal scales). Their head and necks were vigorously manoeuvring to and fro in an apparent bid by each snake to gain a higher head position than its rival, resulting in the formation of additional plaits. This was accompanied by hissing. They were engaged in this activity for about two minutes before the non-resident male retreated back up into the roof cavity, being rapidly pursued by the resident. The 'thuds' heard earlier in the evening then continued intermittently for at least another hour and were observed to result from the rapid separation of the two entwined males.

Observation 3. Mid-evening 5 October and 6:15 pm 9 October 2007, 22-25°C, RH 65%.

On these evenings I (GT) observed two male *B. irregularis* in active pursuit of one another and engaging in brief combat bouts. The pursuer on each occasion was the resident male (the larger of the two) while the pursued male had not been previously recorded. Each of the combat bouts (n = 3) lasted no more than thirty seconds before snakes separated after being plaited along the length of their bodies and a pursuit followed. On the first evening the two males were initially observed on a hand-railing of the veranda with the resident in pursuit of the other male, about 0.5 m away. My presence caused their movements to briefly cease. I retreated but returned several times over the next hour until the snakes could no longer be located. On my second visit, the males were entwined with posterior two-thirds of their bodies plaited and draped over a roof batten. There were rapid movements of the head and anterior body in which the resident male attempted to pin down the non-resident's head; the latter responded by attempting to lift the head up and to the side to avoid being pinned. This was accompanied by hissing and was observed for approximately 30 seconds until the non-resident broke-free and fled with a rapid whip-like action of the tail. It was then pursued by the resident. On my third visit, the posterior third of their bodies were tightly constricted. An adult female was loosely coiled-up 5 m away and draped over a roof batten. On the second evening, the males were again seen entwined and wedged in the gap between the wall and eaves with only their plaited mid-bodies visible. In a later observation one snake (the resident) was in pursuit of the other along a roof batten.

Observation 4. Late in 2003.

In the video footage two adult *B. irregularis* (presumed males) were observed wrestling, entwined and one in pursuit of the other on storage shelving beneath a high-set house. Combatant snakes were easily distinguished by the presence of dark streaks on the labial scales of one of these snakes but there was no obvious size difference between the two. Snakes were initially hanging from a floor beam and were partly draped over some shelving; three meters away was an adult *B. irregularis* (presumed female) that was quiescent throughout the footage and curled-up on a beam but in full view of the pair. The activity between the two combatant snakes was not vigorous but was clearly seen to comprise head-lifting, head-pinning, body-plaiting and constriction. Another behaviour observed several times during head-pinning was looping or arching of the neck (and anterior body) which appeared to be an attempt to displace the opponent's head as it was approaching from above. In addition to these behaviours, snakes were observed biting each other on four occasions. The bites were applied to the neck and mid-body of the opponent. Two of them were quick 'strike and release' bites that lacked force while the other two were gently applied 'grip' bites that were maintained for up to ten seconds. In one

instance a grip bite applied by one snake resulted in a retaliatory bite; snakes separated soon after as they fell to the ground. One of the snakes was the aggressor, initiating three bites (and at least two other attempted bites) and consistently pursued the other.

DISCUSSION

Our observations indicate that male combat occurs in free-ranging *B. irregularis* from coastal north Queensland from late August through to early October. Furthermore, there are two confirmed instances (and a possible third) where male combat has taken place in the presence of an adult female. In each instance the combatant males were of similar size and the individual combat bouts observed, while relatively brief, occurred multiple times between the same pair of males. They were interspersed by periods of pursuit. Male combat has been recorded and studied in captive *B. irregularis* from Guam where it was found to be ritualised and similar to that reported in other colubrid species (Green & Mason, 2000). While the presence of male combat in captive *B. irregularis* suggested that it probably occurred in free-ranging snakes, there are no previously published accounts of this to our knowledge, even for the Guam populations (Rodda *et al.*, 1999b). Trembath and Fearn (2008) speculated, due to the absence of male combat observations in Australian populations of *B. irregularis*, that either combat does not occur or else takes place nocturnally or in cryptic locations such as diurnal retreat sites. Our observations confirm that combat does occur at night when the species is active. This, combined with the fact that it takes place above the ground, might explain why the behaviour has not previously been reported. However, the absence of combat observations is curious given that *B. irregularis* often live in and around human dwellings (e.g., in roof cavities, bird aviaries), as well as some agricultural crops within their range (e.g., banana plantations) presumably increasing the likelihood of such observations occurring (Worrell, 1963: 105; Gow, 1976: 29; McPhee, 1979: 34; Wilson & Knowles, 1988: 373; Wilson & Swan, 2008: 408). Nonetheless, the sight of two snakes intertwined is in our experience erroneously interpreted by the general public as mating rather than combat behaviour and observations 1 and 4 above were interpreted as such by residents.

Similarities between male combat and courtship behaviours have been described in captive *B. irregularis*, making it difficult to distinguish between the two, at least in the early stages (Greene & Mason, 2000). Head-lifting, head-pinning, body-coiling (plaiting), constriction and body/tail lashing were specific male combat behaviours identified in their work and which were also observed by us; other specific combat behaviours identified in their work were not recorded by us, possibly because we did not observe a complete combat sequence. An analysis of Greene and Mason (2000) indicates that ten specific behaviours are shared between the combat and courtship behavioural sequences; six are exclusive to courtship (forward body-jerking, chase (pursuit), mount, tail-lifting, defensive strike posture) and three are exclusive to male combat (body-coiling (plaiting), constriction, body/tail lashing). Pursuit and head-lifting behaviours are common to both, but the extended bouts of head-pinning between males resulting in their bodies becoming plaited and constricted was not seen during courtship. In our observations where the sex of the snakes involved was (in most cases) verified by eversion or probing of hemipenes, there is no doubt the behaviours described were of male combat rather than courtship. We also recorded two specific behaviours that were not recorded in either sequence by Greene and Mason (2000): hissing and biting. These specific behaviours may further serve to distinguish courtship and male combat. Their study also shows that combat bouts were won by the longer and heavier male and this appeared to be the case in our limited observations of combat bouts (observations 2 and 3) where the smaller male fled immediately after combat bouts with the larger male in pursuit.

Mate searching is a likely precursor to both male combat and mating. In north Queensland an increase in male activity (relative to female) is evident in October and November (Trembath & Fearn, 2008; see also Bull & Whittier, 1996). Though observations are few, mating in Australian *B. irregularis* has been reported in October (n = 2; Whittier & Limpus, 1996) which is generally consistent with the timing of male combat recorded in this work (late August to early October).

There are some discrepancies in the literature over the occurrence or non-occurrence of sexual-size dimorphism in Australian populations of *B. irregularis*. Shine (1991b, Table 1) measured the SVL of 206 adult *B. irregularis* and found the mean and maximum SVL was consistently larger in males than in females in each state (NSW, Qld, NT) and also when pooled (Greer, 1997: 112, 116) though no statistical comparison of the means was done to ascertain whether the differences were significant. Trembath and Fearn (2008) found no (statistically significant) sexual-size dimorphism in SVL in any of the three north Queensland populations they studied, though mean and maximum male SVLs were greater than those of females in the two populations in which sample sizes were reasonably large (n > 30). A possible short-coming of their analysis arises because males were not assessed for maturity as they were in Shine's (1991b) study (and in other studies e.g., Rodda *et al.*, 1999a; Savidge *et al.*, 2007). Hence the male sample in Trembath and Fearn (2008) presumably included immature (and thus smaller) males resulting in a smaller mean SVL which confounds the statistical comparison of the means. The criterion for assessing maturity in females was, however, similar for both studies (> 5 vs > 6 mm follicle/egg diameter). Taken in total, the body size data on Australian (and Guam) populations of *B. irregularis* indicate that males attain greater maximum and mean sizes than females, though whether the mean SVLs are significantly different in the statistical sense is equivocal. Furthermore, male *B. irregularis* weighed significantly more than females in all north Queensland populations when SVL was controlled for (Trembath & Fearn, 2008: Table 1). Thus sexual-size dimorphism is evident in *B. irregularis*.

Sexual-size dimorphism where males are larger than females is most common in snakes where males engage in combat for access to females (Shine, 1978, 1994). *Boiga irregularis* therefore conforms to this general trend as anticipated by Shine (1991b).

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A RANGE EXTENSION FOR THE PRONG-SNOUTED BLINDSNAKE *RAMPHOTYPHLOPS BITUBERCULATUS* (TYPHLOPIDAE) IN THE SOUTH-WESTERN SLOPES OF NSW

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Blindsnakes (family Typhlopidae) are represented by 42 species in Australia (Wilson & Swan, 2008). They are fossorial and oviparous and feed primarily on the early life-stages of ants (Webb & Shine, 1993a; Greer, 1997). Despite detailed investigations on their foraging ecology and prey relationships (Shine & Webb, 1990; Webb & Shine, 1993a, b), they remain one of the poorly known groups of Australian reptiles, particularly in regards to abundance, taxonomy and biology (Greer, 1997; Rabosky *et al.*, 2004). Likewise, because of their cryptic behaviour geographical distributions for most species are incomplete. This is apparent in the South-western Slopes (SWS) biogeographical region of New South Wales, where a literature review and database search of the NSW National Parks and Wildlife Service and Australian Museum wildlife atlases revealed a paucity of records for three species south of the Murrumbidgee River. Records included three *Ramphotyphlops bituberculatus*, nine *R. nigrescens* and two *R. proximus* (Swan *et al.*; 2004; NPWS, 2008; Australian Museum, 2008). In addition, Michael (2004) recorded *R. proximus* north of Albury and Cunningham *et al.* (2007) recorded *R. nigrescens* 10 km SE of Tarcutta. Both *R. bituberculatus* and *R. proximus* are arid-adapted species whereas the majority of the distribution of *R. nigrescens* occurs in more humid environments (Wilson & Swan, 2008), although all three species are sympatric near Wagga Wagga, NSW (Annable, 1995), where *R. nigrescens* is at the western limits of its range. Here, we report a record of *R. bituberculatus* from Mates Gully Travelling Stock Reserve (TSR) near Tarcutta, NSW (35°15'23.11"S 147°41'20.63"E).

On 11 November 2006, at 2030 hrs a sub-adult (150 mm total length) *R. bituberculatus* was observed on an unsealed vehicle track during night-time surveys for arboreal marsupials. The specimen was found to have sustained a head injury (possibly from being trampled) and was subsequently lodged with the Australian Museum (AMS R171160). Weather conditions during the day reached a maximum of 32.2°C and remained warm and humid into the night (44% relative humidity) attaining a minimum of 15.8°C (Bureau of Meteorology, 2008). Soil conditions were dry although some light precipitation had occurred prior to the observation.

Mates Gully TSR covers approximately 95 ha of high quality remnant Box-Ironbark forest on poor nutrient meta-sedimentary derived soils. It is classified as western slopes dry sclerophyll forest. The vegetation is dominated by Mugga Ironbark *Eucalyptus sideroxylon*, Grey Box *E. microcarpa*, Red Stringybark *E. macrorhyncha* and native shrub species include *Acacia pycnantha, A. paradoxa* and *Cassinia laevis*. The ground cover supports a rich variety of native forbs and grasses interspersed with cryptogam-encrusted soil. Fallen timber and termites are abundant and some grazing and illegal firewood collection occurs periodically. In general, the TSR is an excellent example of high quality remnant vegetation situated in a highly modified agricultural landscape, measurable by the atypically high population densities of threatened species, including the Squirrel Glider *Petaurus norfolcensis* (Crane *et al.*, 2008) and Swift Parrot *Lathamus discolor*, as well as supporting an extensive suite of declining woodland birds (Lindenmayer *et al.*, unpublished data).

Our new record of *R. bituberculatus* is a range extension of approximately 35 km south-east of the Wagga Wagga records (Swan *et al.*, 2004; NPWS, 2008) and 55 km south of the Ulandra Nature Reserve record (Daly, 2004; NPWS, 2008). Furthermore, it represents an addition to the 25 reptile species (six of which are elapids) previously documented for Mates Gully TSR (Sass, 2003). This number of reptile species from a relatively small, intact lowland patch of remnant vegetation is particularly rare in the SWS (Cunningham *et al.*, 2007); a region highly modified by agricultural activities (Benson, 1999; Lindenmayer *et al.*, 2005). Thus, our new record of *R. bituberculatus*, and addition to the herpetofauna of Mates Gully TSR, highlights one of the many conservation values of the travelling stock reserve network in NSW.

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CAPTIVE BREEDING OF THE SLENDER TREE FROG (*LITORIA ADELAIDENSIS*) AT PERTH ZOO

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ABSTRACT

The Slender Tree Frog (*Litoria adelaidensis*) is a common species endemic to the south-west of Western Australia. Perth Zoo has maintained Slender Tree Frogs since 1997 as a display and for educational purposes with successful breeding occurring in most years. This paper discusses the management and husbandry methods required for the successful care, breeding and raising of tadpoles, based on the methods used at Perth Zoo.

INTRODUCTION

The Slender Tree Frog (*Litoria adelaidensis*) is an elongated slender frog with either brown or green colouration. Reaching not more than 50 mm in length, this little frog is poorly researched although very common in the south- west of Western Australia. In 1999, *Batrachochytrium*, commonly known as chytrid fungus (Aplin & Kirkpatrick 2000), was first recorded in wild populations of the Slender Tree Frog within zoo grounds. Chytrid fungus is responsible for declines of amphibian numbers around the world (Berger *et al.*, 1999), but does not seem to be affecting Slender Tree Frog populations around Perth. However, the susceptibility of the Slender Tree Frog to this disease means that conservation measures need to be enacted before the species goes into decline.

An understanding of the captive requirements and the development of husbandry techniques to facilitate breeding and rearing of frog species will help preserve the species should wild populations become endangered (Mahony *et al.*, 1999; Marantelli, 1999). From a captive husbandry perspective, it is better to be able to work with a species prior to a decline in the wild population so that captive techniques may be developed while the species is still secure. Once husbandry methods are developed on a common species they may be adapted and applied to closely-related threatened species.

There is very little information on the captive reproduction or the long-term management of Slender Tree Frogs. In 1997 permission was granted to collect several frogs and maintain them as a captive colony within the wetland exhibit at Perth Zoo. This colony was managed successfully with spawn produced and tadpoles and metamorphs being raised most years.

HOUSING AND MAINTENANCE

The Slender Tree Frogs at Perth Zoo are housed in a 1400 mm long x 800 mm wide x 1000 mm high display enclosure. The exhibit is mock rock with a small waterfall and a pond heated by a 100 Watt aquarium heater. In spring and summer the pond water is maintained at 23 – 27°C. Living plants such as reeds and sedge are planted in the exhibit, and both natural as well as artificial lighting (via a 400 Watt Sodium vapor bulb maintained on an 11 hour cycle) is provided mainly for plant maintenance. The ambient air temperature fluctuates according to natural weather conditions and ranges from 10 – 35°C. Daily servicing of this enclosure consists of removing faecal materials, cleaning the filter medium, watering the plants and cleaning windows.

Small aquaria 500 mm long x 250 mm wide x 300 mm high are used to hold Slender Tree Frogs off-display. One half of the enclosure sits on a heat pad thermostatically set at 25 – 28°C. A 35 ml water bowl sits at the non-heated end of the aquarium with sphagnum moss covering the bottom to a thickness of about 5 cm. Several small branches are utilized as sitting perches for the frogs. Daily servicing of this enclosure is similar to the display frogs above.

FEEDING

All of the frogs at Perth Zoo are fed twice weekly, although this is adjusted accordingly if weight or health issues arise. The Slender Tree Frogs are primarily fed small live insects (crickets, termites and moths) which are dusted in calcium carbonate prior to feeding - except for one day per week when this is substituted with a Herptevite / calcium carbonate mix.

HEALTH

The Slender Tree Frog colony has maintained a good level of health with the average longevity being 7.1 years (n = 9). A weight problem occurred in some of the frogs on a three day per week feeding schedule but this was managed by reducing the feeding frequency to two days per week. Two frogs developed ambulation problems associated with the hind legs. These frogs were euthanased, with histopathology finding degenerative changes in the spinal cord and muscles of the spine and hind legs. Another frog that died in the enclosure was found on histopathology to have lymphoid leukaemia that had affected its liver, lungs, kidney and intestine.

REPRODUCTIVE INFORMATION AND BEHAVIOUR

Calling has been heard in the captive group from late August to early September, similar to that observed in wild populations (Tyler *et al.*, 2000) with amplexus observed as early as 20 August. Calling occurs during the day or night from reeds close to the water's edge or from a good vantage point nearby. Females generally sit in the reeds. The earliest recording of egg spawn was on 8 September and the latest on 29 September. A total of five spawns were recorded during the 21 days with two collected containing 150 and 211 eggs respectively. Of the latter spawn, 78 eggs were fertile and hatched. No multiple spawns were observed by any one female and there was no care of the spawn by either parent once laid. Below is a record of one of these breeding incidents.

- 28 September, a pair observed in amplexus in the afternoon on the side of the pond in reeds.
- 29 September, 211 eggs counted. Water temp. 26.5°C, pH 7.2, air temp. 24 – 27°C. Spawn was laid in the water along the side of the pond. Spawn was deposited amongst several decomposing reed leaves and on the mock rock with some spawn directly on the pond floor. Eggs at stage 1 - 5 (Gosner, 1960).
- 29 September, 78 eggs appeared; eggs at stage 15 - 16 (Gosner, 1960).
- 30 September, eggs stage 17 - 18 (Gosner, 1960).
- 1 October, eggs at stage18 - 19 (Gosner, 1960).
- 2 October, eggs starting to hatch by tadpoles at various stages of development, i.e. stages 20 - 21 (Gosner, 1960)
- 3 October, some tadpoles at stage 23 (Gosner, 1960). The head length, tail length and total length was measured for 10 tadpoles (Table 1).

The tadpoles were transferred to a rearing pond where water temperature ranged between 20 – 24°C (depending on air temperature). See below in tadpole management.

In autumn 2005 through to late summer 2006, we supplied heat to the frogs year-

Table 1. Head, tail and total size of free swimming tadpoles (n = 10).

Tadpole number	Head size (mm)	Tail size (mm)	Total length (mm)
1	3.10	5.85	8.95
2	2.85	5.95	8.80
3	3.85	5.15	9.00
4	2.75	5.80	8.55
5	3.05	6.25	9.30
6	3.05	5.20	8.25
7	3.70	6.15	9.85
8	3.20	5.30	8.50
9	3.00	5.45	8.45
10	3.15	6.10	9.25
Average	**3.17**	**5.72**	**8.89**
Stand Error of the Mean	**0.35**	**0.41**	**0.48**

round (pond water at 26°C with a basking spot at 30°C). No breeding took place that year and from this we suspect this species requires seasonal changes as a stimulus for reproduction.

TADPOLE REARING

Tadpoles were removed from the exhibit once they were free swimming to prevent them being pulled into the filter and dying. They were moved into a plastic tub 650 mm long x 410 mm wide x 280 mm high that was filled with water to about 180 mm deep. No more than 25 tadpoles were transferred into each tub to prevent overstocking. The water supply was tap water that had been sitting for several days as well as some of the water from the display pond. Little cleaning was done to the tadpole tub and water levels were topped up on a weekly basis. An air stone was placed at one end to oxygenate the water and create a small amount of water movement. The enclosure had river rocks on the floor and was covered with detritus (old *Eucalyptus* sp. and *Melaluca* sp. leaves) 20 - 30 mm thick for the tadpoles to eat. This was given *ad lib* whenever the tadpoles required more, generally once per week and aided in raising healthy tadpoles. A problem we found with outside pond detritus was the presence of dragonfly and damselfly larvae. We had lost several tadpoles through predation by these aquatic insects before realizing the problem. To prevent this problem we now store our water tubs in an enclosed aviary, to prevent unwanted insects from also using this water source.

Young tadpoles grew quickly and growth slowed as they get older. Metamorphosis started in mid to late December and froglets started appearing from the 15 January, 104 days after hatching. By 16 February (150 days after hatching) all the tadpoles had completed metamorphosis. In one of the tadpole groups, two individuals did not commence metamorphosis with one remaining as a tadpole until June (approximately 255 days) and the other until August (approximately 316 days).

METAMORPHOSIS MANAGEMENT

Once metamorphosis commenced, small leafy branches (mainly *Acacia* sp. and *Casuarina* sp.) were placed in the water. *Casuarina* branches were particularly good as the thin leaves made spotting froglets much easier. The developing froglets were often observed in the branches and climbing onto them when emerging from the water. Once they had left the water they were transferred to a rearing enclosure which was a 500 mm long x 250 mm wide x 300 mm high glass aquarium. A small heat pad sat under one end to supply a small amount of heat (thermostatically set at 25 – 28°C). A water bowl was placed at the other end with a thin layer of sphagnum moss over the bottom. Several leafy branches were placed in the enclosure to create a lot of perching points. Froglets started feeding almost immediately on very small live crickets dusted in calcium carbonate. Termites were also offered to assist in stimulating feeding responses.

CONCLUSION

The Slender Tree Frog appears to be relatively easy to maintain and breed in captivity, with minimal variations required to their captive husbandry to stimulate breeding. The most important of these appears to be a requirement to vary the temperature in the enclosure to emulate the change of seasons that would occur in the wild. Very few problems have been recorded in the rearing of tadpoles, metamorphs and frogs. The deaths of several tadpoles due to predation by dragonfly and damselfly larvae was the most significant of these and has been prevented by only using detritus that has been produced in a controlled environment. Health problems that have been observed in the adults are considered age-related issues. By maintaining this species long term we have been able to observe and describe the captive management of the species.

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NOTES ON REPRODUCTION IN THE SKINK *SAPROSCINCUS ROSEI*

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INTRODUCTION

Saproscincus rosei is a small, surface active, diurnal skink occurring in rainforest and moist eucalypt forest between Gympie (Queensland) and Barrington Tops (NSW) (Sadlier *et al.*, 1993). The species was included in the composite *Saproscincus challengeri*, before being described by Wells and Wellington (1985) and redescribed by Sadlier *et al.* (1993), and includes several distinct regional forms (Sadlier *et al.*, 1993; Swan *et al.*, 2004).

Reproduction in the related *Saproscincus mustelinus* (Weasel Skink) has been relatively well documented (German, 1986; Banks, 1992; Ehmann, 1992; Shea & Sadlier, 2000; Manning & Andrews, 2003), while information for *Saproscincus rosei* is minimal and complicated by taxonomic confusion. Ehmann (1992) reported that *Saproscincus challengeri* (at that time including *S. challengeri, S. rosei* and *S. spectabilis*) had a clutch size of between two and nine eggs with up to 45 eggs found in communal oviposition sites.

The following observations on reproduction by *Saproscincus rosei* were made during a field survey of the vertebrate fauna of Bruxner Park Flora Reserve and Ulidarra National Park, near Coffs Harbour in *Gumbaynggirr* Aboriginal Country in the New South Wales north coast IBRA bioregion (Murphy & Murphy, in press).

OBSERVATIONS

A gravid adult *Saproscinus rosei* was captured live by hand on a road in rainforest in Bruxner Park Flora Reserve on 5 January 1997. The animal had a snout-vent length (SVL) of 55 mm and a total length (TL) of 113 mm. Five eggs were laid on 8 January 1997. The mean egg size was 10.0 mm long (range 9.8 – 10.5mm) by 8.5 mm wide (range 8.3 – 8.8 mm). The eggs were placed in a plastic container with moist soil, buried just below the soil surface and under a layer of leaf litter, and were kept at room temperature out of direct sunlight. Four of the eggs hatched on 11 February (34 days after oviposition) and the fifth failed to hatch. The average size of hatchlings was 19.4 mm SVL (range 19.0 – 20.0 mm) and 43.4 mm TL (range 42.0 – 44.5 mm). The relative size of hatchlings to adult averaged 35.2% by SVL. The adult female (R151355) and four hatchlings (R151934, R151935, R151936 and R151937) were lodged in the Australian Museum, Sydney.

DISCUSSION

The clutch size, egg size, incubation period and relative hatchling size for *S. rosei* documented here are comparable to that reported for *Saproscincus mustelinus*. Manning and Andrews (2003) recorded clutches of 5-9 eggs in *S. mustelinus*, with clutch size positively correlated with female SVL, and an incubation period of 31-37 days. Egg size in *S. mustelinus* has been recorded as averaging 10.70 x 6.61 mm (Banks, 1992) and 9.50 x 6.14 mm (Manning & Andrews, 2003) and relative hatchling size averaging 37.5% of adult size by SVL (Manning & Andrews, 2003).

Clutch size has been reported in *Saproscincus tetradactylus* as comprising of two eggs (Ehmann, 1992; Turner, 2006) and as three eggs in *Saproscincus oriarus* (Sadlier 1998). Both of these species are markedly smaller than *S. rosei* (Ehmann, 1992; Cogger, 1992; Swan *et al.*, 2004).

Additional observations of reproduction in the various *Saproscincus* species are needed to provide a larger dataset enabling more accurate identification of reproductive parameters

and consideration of inter-specific differences in reproductive strategies.

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A BIOGEOGRAPHICALLY IMPORTANT SOUTHERN RANGE EXTENSION OF THE NORTHERN DISTRIBUTION OF THE ROUGH-SCALED SNAKE (*TROPIDECHIS CARINATUS*)

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Rainforests along the east coast of Australia represent a series of disjunct refugia restricted to the Great Dividing Range, which span 3,000 km along the east coast of the Australian continent (Nott, 2005). Two distinct bioregions well known for their high biodiversity and endemic species diversity are the subtropical rainforests of north-eastern New South Wales and south-east Queensland, and the Wet Tropics World Heritage Area of north-east Queensland, Australia. These two disjunct and geographically isolated bioregions both contain rainforest and wet sclerophyll forest and share a number of vertebrate species restricted to these habitats (Cogger, 2000). The two regions are separated by approximately 900 km of unsuitable habitat. Rainforests of the Wet Tropics World Heritage Area in north-east Queensland contain a high proportion of cool-adapted endemic vertebrate species, including many endemic reptile species (Williams *et al.*, 2003). One species that occurs in both bioregions, but not in the intervening area, is the rough-scaled snake *Tropidechis carinatus*, a dangerously venomous elapid snake species that reaches a total length of 1.2 metres (Cogger, 2000). The northern population of *T. carinatus* occurs between the Windsor Tableland (16.21°S 145.01°E) in the north to the Bluewater Range in the south. Locality records from the Queensland Museum indicate that the southern-most records for *T. carinatus* of the north Queensland population are from the Bluewater Range (19.10°S 146.23°E), with an additional record from Mt Spec (19.00°S 146.10°E; datum: WGS84; A. Amey, Qld Mus., pers. comm.), a few minutes slightly further north. This note provides two additional records of *T. carinatus* from Mt Elliot, a locality 45 km further south than any previous record for this population of *T. carinatus*. This site is further noteworthy as it is isolated from the Bluewater Range by a wide area of dry, open woodland that is unsuitable for occupation by montane rainforest-restricted species. The group of mountains associated with Mt Elliot is acknowledged as an outlier and southernmost limit of the Wet Tropics World Heritage Area (Williams, 2006). Mt Elliot has a maximum elevation of 1221 m and receives approximately 1200 mm rainfall per annum, with areas of higher elevation receiving more (Williams *et al.*, 1993).

While conducting passive searches for reptiles in rainforest on Mt Elliot, on 25January 2006 at 1121 hr EST (19.3060°S 146.5700°E; datum: WGS84; elev. 858 m), I observed an adult rough-scaled snake (0.70 m total length) moving through dense leaf-litter and undergrowth. Due to the extensive vegetation cover the snake was not collected, but was observed from 1-1.5 m distance for approximately 25-30 seconds. This enabled adequate time to observe the keeled dorsal scales, prominent supraocular scale and absence of a loreal scale. *Tropidechis carinatus* superficially resembles the harmless, but similarly keeled-scaled colubrid species *Tropidonophis mairii* from which it differs by possessing the latter two features (Cogger, 2000). On the same day at 1343 hr EST, a second adult individual, as defined by differences in pattern and coloration (0.8 m total length), was observed from 1.0-1.5 m for approximately 15-20 seconds in identical habitat (19.3484°S 146.6835°E; datum:

WGS84; elev. 980 m) moving under branches of the crown of a recently fallen tree. Both individuals occurred on the east face of the Mt Elliot in sites with high levels of solar radiation caused by tree falls and were at elevations greater than 850 m. The substantial range increase reported herein represents a new southern limit to the northern population of *T. carinatus*.

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HERPETOLOGICAL NOTES

RESPONSE OF A *CTENOPHORUS FORDI* TO TEMPORARY SURFACE WATER IN BILLIATT CONSERVATION PARK, SOUTH AUSTRALIA

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Australian reptiles that live in arid regions have adapted to an unpredictable and low rainfall regime (Murrell, 1984). One successful inhabitant of arid regions is the Mallee Dragon, *Ctenophorus fordi* Storr 1965. This small species of agamid (50 mm snout-vent length) can obtain high densities in the arid habitats it occupies, where surface water is usually absent (Cogger, 1969). At 0900hrs on 9 October 2008 a Mallee Dragon was observed standing next to a clump of spinifex (*Triodia* sp.) on red sand, in Billiatt Conservation Park, South Australia (34°55.560'S 140°24.197'E; WGS84). I first noticed the lizard when I was approximately one metre from it. After observing it for several minutes, I squatted down and urinated on the sand for approximately 10 seconds, creating a shallow puddle. The Mallee Dragon ran directly and immediately into the puddle of urine, then put its head into the urine and shook vigorously. It stayed in the puddle for several seconds and when the urine had entirely infiltrated the sand it departed. The observed Mallee Dragon responded to a spontaneous water source by immediately approaching and then engaging the resource. This suggests that access to temporary surface water may be beneficial to these arid-adapted animals and some Mallee Dragons will opportunistically approach such temporary water when available. Alternatively, a chemical cue from the urine may have instigated the response; the attractiveness of differing water sources could be explored in future research. Knowledge of this behaviour could be beneficial as a novel survey technique, to attract or lure Mallee Dragons.

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ARBOREAL ACTIVITY IN THE GOLDEN-CROWNED SNAKE *CACOPHIS SQUAMULOSUS*

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Arboreal activity is considered uncommon in Australian elapid snakes and has not been reported in crowned snakes (*Cacophis*) before. Here, I report observations of arboreal activity in the golden-crowned snake *Cacophis squamulosus* at Kondalilla National Park, south-east Queensland; the first such observations for the species and the genus.

In November 1994, whilst waiting for dark at Kondalilla National Park (26°40'18"S 152°52'12"E), a golden-crowned snake was seen descending the vertical trunk of a tall brush box (*Lophostemon confertus*) in wet sclerophyll forest. When first spotted, the snake was 7 or 8 metres above ground, creeping slowly towards the forest floor. When approached, it turned and began climbing quickly upwards again, disappearing around the back of the brush box tree. After several minutes waiting, the snake was seen descending the tree again, eventually reaching the forest floor. The animal seen climbing was estimated to be 0.7-0.8 m in length, around the size of a large adult female *C. squamulosus* (Shine, 1980). Observations were made on dusk, along a sealed walking track under warm wet conditions, following afternoon showers.

Based on the above observations, *C. squamulosus* appears capable of climbing trees with relative ease. This ability may be due, in part, to the light weight and narrow body of *C. squamulosus* (attributes likely to assist snakes with climbing; Shine, 1991; Greer, 1997). The ease with which *C. squamulosus* was seen climbing at Kondalilla NP may also be partly attributed to the somewhat rough bark characteristic of brush box trees. Lacking the keeled or notched ventral scales of more arboreal elapid species (e.g., *Hoplocephalus* and *Tropidechis* spp; Wilson & Swan, 2008), *C. squamulosus* would most likely struggle to climb trees with smoother, finely-fissured bark (however, see Meyer *et al.*, 2009).

Since the diet of *Cacophis* species comprises mainly terrestrial scincid lizards and not arboreal prey (Shine, 1980), *C. squamulosus* is unlikely to climb trees in search of food. As such, arboreal activity is likely to be rare in this species. *Cacophis squamulosus* might, however, climb trees to escape or avoid terrestrial predators (e.g., large elapid snakes). Further study of arboreal activity in crowned snakes is required to determine whether or not this is the case and whether or not other *Cacophis* species might behave in a similar fashion.

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NOTES TO CONTRIBUTORS

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Photographs – High resolution digital, black and white prints or colour slides are acceptable.

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Manuscripts may be submitted to the editor electronically, via email (gshea@mail.usyd.edu.au) or on CD. Manuscripts submitted electronically must be in Word format, with photographs as separate jpg or tif files.

Articles should not exceed 12 typed double spaced pages in length, including any illustrations.

REFERENCES

Any references made to other published material must be cited in the text, giving the author, year of publication and the page numbers if necessary. At the end of the article a full reference list should be given in alphabetical order. (See this journal).

Manuscripts will be reviewed by up to three referees and acceptance will be decided by an editorial committee. Minor changes suggested by the referees will be incorporated into the article and proofs sent to the senior author for approval.

Significant changes will require the article to be revised and a fresh manuscript submitted.

REPRINTS

The senior author will receive a PDF copy of their article.

Golden-crowned snake (*Cacophis squamulosus*) from Wilson River, NSW (Photo: G. Shea).
See article on this species on p. 124

Saproscincus rosei from Styx River State Forest (Photo: G. Shea).
See article on this species on p. 119.